FOOD TECHNOLOGY

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THIS BOOK

is dedicated by the authors
to the Scientists, the Technologists, the Engineers
and the Industrial Leaders of broad vision
who have cooperated
in the application of scientific research
and have thus jointly made possible
the great advances which have characterized
the food industries of America

PREFACE

From the dawn of history, the primal instinct of hunger has given man a compelling interest in the problems of securing and maintaining his food supply. First as a hunter and then as agriculturist and herdsman he acquired a simple but constantly enlarging knowledge of production and conservation. The growth of towns and cities involving larger needs and new difficulties in storage and transportation added to his problems and gradually transformed food production from an occupation to a business. Even then the danger of shortage and starvation faced the increasing populations, and primitive forms of food preservation were learned by experience. With the use of science the nature of various foods and the real significance of the principles of nutrition began to be known.

In the past five decades this knowledge has vastly increased, and especially since the turn of the present century there has been astounding development in food technology. Today the food industries, in which crude domestic methods have been transformed into highly organized and accurately controlled procedures for food manufacture and conservation, constitute one of the greatest and most important of our commercial enterprises, and one of the most interesting chapters in the history of specialized industries.

Food technology in the sense in which it is used in this work comprises the economic application of the laws and processes of biology, physics, chemistry, and engineering in the preparation and preservation of food products which are nutritionally of high quality, which are handled in a sanitary manner to prevent dangers from infection, and which may in many instances be kept for long periods or transported from regions of abundance to those of scarcity.

The published literature on food is voluminous, and many excellent books dealing with special phases of food production and preservation are available. As teachers who have for many years been specially concerned with the training of students who were to find places in the great food industries, we were unable, however, to find any single volume that could serve as the basis for a broad and constructive treatment of this important field of food technology. We have, therefore, brought together in this book a portion of the material used in our courses and we have attempted to emphasize the fundamental principles involved in the various methods of food manufacture and treatment rather than to give highly detailed accounts of the manipulations carried out in each particular case.

It is our hope that this volume may be of service to others than our own students, and that food manufacturers, nutritional directors, and those concerned with the official supervision and inspection of food supplies, as well as teachers and to some extent the general public, may find this volume of interest and value. Its production has been in part due to the result of many years of close association with food industries and the study of special types of problems that have arisen therein.

Many scientific journals, bulletins, and books on food have been consulted in preparing this work, and we wish to express our appreciation and gratitude to their authors. We have attempted to give special credit in the text where definite reference has been made. If any omissions have inevitably resulted, we should be glad to have them brought to our attention so that due credit may be given in any second printing.

We are indebted to many persons among whom are numerous friends, colleagues and former students, who have assisted directly or indirectly in making this text possible. To them we offer sincere appreciation for their services and kindness. Particular thanks are due Dr. A. W. Bitting for his cooperation in contributing the chapter on Canning, a subject on which he is a leading authority. Our deep indebtedness to our colleague, Dr. Cecil G. Dunn, is acknowledged for his great assistance in the compilation of material and statistical information and his splendid cooperation. Others to whom special recognition is due are Mr. Milton E. Parker and the late Mr. Joseph F. Phelan who have aided in the chapters on Milk and Dairy Products, and to Mr. J. M. Brown for helpful criticisms concerning the material on Sugar.

The especial courtesy of Dr. L. V. Burton, Editor of *Food Industries*, in placing at our disposal numerous flow charts and photographs which have been used in the text is gratefully acknowledged. Other organizations that have kindly cooperated in furnishing photographs include the McGraw-Hill Book Company, General Mills, Inc., Beech-Nut Packing Company, Cherry-Burrell Company, the United States Department of Agriculture, DeLaval Separator Company, Proctor and Schwartz, Inc., Milk Plant Monthly, General American-Pfaudler Company, Walker-Gordon Laboratory Company, and the Institute of American Poultry Industries. To each we extend our appreciation.

A companion volume considering the more detailed technological aspects of certain of the food industries for the use of more advanced students is contemplated in the not too distant future.

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CHAPTER I

INTRODUCTION

In an address given by Dr. Isaiah Bowman in 1935 before the American Association for the Advancement of Science, he said: "Over the greater part of the earth and for at least three-fourths of our two billion planetary population, the will to eat is the primary urge of the eternally hungry man."[1]

It is easy to understand why from time immemorial the problem of food supply has occupied the mind of man since it springs from one of the most primal of man's instincts—hunger.[2] To satisfy the desire and the need of food the savage moved his habitation from hunting ground to hunting ground, depending on the meat, fish, or wild fruits and plants that might be found and later developed his primitive agriculture to guard against starvation. Such conditions may be found today in some of the more remote districts of the interior of Africa. Wars have been waged for food, and the instinct of self-preservation motivated the migrations of man as well as of lower creatures. At a much later period the production of food became a domestic industry engaging man's entire attention, and exchange of foods between neighboring people by barter constituted one of the early forms of trade.

From some such simple beginnings has arisen one of the most important, complex, and interesting of the social and economic problems of the present time—the world's food supply. Here is a problem not only personal and of immediate interest, but one the ramifications of which extend into many phases of national and international welfare, and which is intimately intermixed with the movements and numerical changes of populations, with the developments of science, and with that inexorable factor in the fate of civilizations, time.

In a superficial way, and from the standpoint of temporary necessities, our vision of the problem changes from time to time, depending on those elusive factors which we call world conditions. As we recall the meatless and wheatless days of two decades ago and compare them with the present days of agitation regarding farm relief, price fixing, control of surplus,

[1] Bowman, I., *Science*, **82**, 285, 1935.

[2] Prescott, S. C., *Tech. Rev.*, **31**, No. 8, July, 1929.

and the other phases which enter so frequently into the lengthy discussions of the moment, we are brought to the conclusion that in a few brief years the barriers of a reputed impending food shortage have again been pushed back. The dire calamity predicted by Malthus in 1789 and to a lesser degree by Sir William Crookes a hundred years later, is still too far in the future to cause grave concern.

The scientist, however, thinks and works not merely for himself and the momentary need but, with the spirit of genuine altruism and human service, he must perforce envision a future which in the life of the individual may be remote but in the life of a nation or of a civilization is, in Scriptural phrase, but a day.

In order to foresee and estimate certain trends for the future we must review the story of food supply for the period of our national life. At the end of our Colonial Period, before the steamboat and the railroad had begun the contraction of the globe, man lived almost as he had lived for a thousand years. The industrial revolution had begun in England, and to some extent the change was felt in other parts of Europe, and even in the Colonies, but the arts of peace were still largely small-scale domestic arts. Invention had scarcely begun to modify the methods of labor; food supply was still largely a matter of individual effort and manual labor. It is not surprising that a man of the mental capacity of Benjamin Franklin should have found these conditions worthy of discussion and analysis, for to him belongs the credit of the first modern treatment of the relation of population to food supply. He was followed shortly by Hume and Wallace in Great Britain, and later by Townsend. In 1798 the thoughtful and pessimistic Malthus, noting the force of their arguments and the public disinterest in them, felt impelled to elaborate this doctrine, to call attention anew to the relation between population and subsistence, and to the dangers that were certain to follow the unrestricted increase in the numbers of mankind.

In 1800 the population of the known portion of the globe was, as nearly as can be estimated, about 750 millions, probably half of it in China, the home of real agriculture. Cities were relatively few and small. New York had but 60,000 inhabitants, although London was even at that time a city of a million souls. In America the population had hardly begun to stream into the great central valley but was almost exclusively on the Atlantic slope. The West was *terra incognita*. Canada, aside from the valley of the St. Lawrence, was a frozen blank; Australia, a mystery. Other parts of the globe, now of great significance from the standpoint of food supply, were then of no importance in this respect.

There are three principal areas of dense population, Southeastern Asia, Europe, and North America. According to Baker,[1] the first, South-

[1] BAKER, O. E., *Geog. Rev.*, July, 1928.

eastern Asia, including India, Siam, Indo-China, the East Indies, China, and Japan, contains about 900 million people, roughly one-half the population of the world. The second region, Europe, contains about 500 million, or about one-fourth the world's population. North America contains about 150 million, or one-twelfth of the population of the world.

The population of North America, which has three times the amount of arable land per person that Europe possesses, and six times that of Southeastern Asia, has for 100 years been increasing at a much more rapid rate than the other two regions. This population growth rate in North America has been due not only to natural increase but also because of a continued and often very large immigration, and the lower rates elsewhere are attributed in part to wars, famines, pestilence, and emigration.

Although the population increase in the United States has shown a growth unparalleled in history, the rate of increase for the past two decades has materially lessened, a fact due only in part to more restricted immigration. Europe's population increase has been numerically large but its rate of increase is at a lower level. Moreover, the standards of living have been raised, which generally signifies an increase in the per capita food consumption.

The conditions of a hundred years ago form a striking contrast to the conditions of today, with more than half of our people living in cities; with railroads, steamboats, automotive vehicles, and airplanes as rapid means of transportation; and with the telegraph, the telephone, and the wireless for instantaneous communications between distant points. These factors have vitally affected the equation of supply and demand. Furthermore, new areas have been opened up for cultivation, exploration, and migration.

As agriculture and food supply are primarily dependent on suitable land for crop production, the extent of arable soil on the earth's surface is of great importance. Large centers of population came into existence first in regions where there was land sufficient to produce crops which could sustain those increased populations. The intervening distance between the farmer and the consumer increased as transportation was developed and changed progressively from man power to pack animal, pack to wagon, wagon to railroad; rafts to boats, sailboats to steamboats. The size of the great metropolitan areas and density of populations have increased with a mounting dependence on transportation facilities for the food supplies. The staple foods may come from any country on the face of the globe, while perishable products may be hastened on their journeys by refrigerated express trains, fast boats, or even by airplanes.

In the general consideration of a world food problem our thoughts inevitably turn to the great staples which have for many years formed the

basis of the dietaries of civilized man. We may tabulate these staples into two relatively simple lists:

Foods of plant origin	1. The cereals: wheat, rice, corn, oats, rye, and barley 2. Sugar: from sugar cane, beets 3. Vegetables: potatoes, sweet potatoes, cassava, beans, peas 4. Fruits: such as banana and plantain
Foods of animal origin	5. Meats; including beef, pork, mutton, poultry 6. Dairy products 7. Fish and seafoods

Perhaps the one food universally considered as essential is cereal, but the importance of the other foods depends largely on the food habits of the individual. These habits have been developed in part through necessity, but national nutritional characteristics have grown up largely on the basis of the abundance of the foods most utilized or most easily obtained.

In certain respects all mankind is dependent on natural forces because with the exception of salt all our foods are of plant or animal origin. If one considers this situation further, it is apparent that all our food animals eventually owe their existence to plants. Even carnivorous animals obtain their food supply by preying on others which do depend on plant foods. The plants, in turn, are dependent on those comparatively simple chemical substances they obtain from the soil and the air, which are essential for their development. In addition to the chemical elements needed for their nutriment, sunshine or light irradiations provide the energy necessary for the synthetic processes which enable the plants to form sugars, starches, and other complex molecular combinations, including the proteins and fats, that make up the protoplasm of plant tissues. These fundamental changes could not progress, however, without the presence of chlorophyll which exerts a catalytic action on the necessary reactions.

Chlorophyll is the green coloring matter which is present in all green plants. It has been subject to much investigation, and studies of its chemical composition have shown that instead of one compound there are in reality two closely related chemical compounds concerned.[1] Without chlorophyll, and the synthesis by plants of foods in the form of carbohydrates, proteins, and fats, man would be unable to exist, as there would be no food supplies.

If man possessed the key of knowledge which unlocked the mysteries of nature completely, it might be desirable to gather together simple chemical compounds such as carbon dioxide and water which the plants use, incorporate the proper catalyst, and conduct the synthesis of sugars

[1] See SPOEHR, *Stanford Univ. Ann. Rev. Biochem.*, **2**, 453, 1933.
ARMSTRONG, *Chem. Ind.*, **52**, 809, 1933.

and starches on a gigantic scale in the presence of man-made sunlight or ultraviolet light. If such were possible, the problems of man's food supply would indeed be simplified, but unfortunately this is not yet possible. Instead we are forced to depend for our foods on the vital synthetic laboratories of tiny plant cells, which in countless myriads, through the combined agency of sunlight, chlorophyll and their own vital activities, furnish the compounds that eventually serve in diverse forms as foods for man and provide sustenance for our food animals.

Natural selection or the survival of the fittest has been going on for countless centuries, long before man became interested in the cultivation of special crops for his own sustenance, and will doubtless continue to be a factor in this respect. It has been possible, however, to duplicate certain types of natural conditions and develop plants of tropical and subtropical requirements under glass for commercial crops, but this of course is but a minor part of our present-day agriculture.

Environmental conditions govern to a great extent not only the yields which may be expected from certain crops in a given area but dictate the types of crops which will grow at all in that area.[1] Much has been done in the past century in the way of introducing crops from other lands which will grow in our farm regions to better advantage than some which we formerly cultivated under less favorable conditions with lower efficiency.

The selection of plants, plant breeding, genetics, and its application to agriculture, soil chemistry, and physics, irrigation, the development of chemical fertilizers, the utilization of biochemistry in the study of chlorophyll and its function, the study of insects and insecticides, the science of bacteriology and its role in the study and prevention of plant and fungus diseases and numberless other aspects of science in relation to the growth of plants indicate only a few of the fronts on which man has worked to aid his growing field of knowledge concerning the procurement of his primary food supplies through the agency of living plants.

A closely allied field which requires and receives equally devoted attention is that of the development of animal food supplies through experimental research involving our food animals. Man is no longer able to depend on the fortunes of the hunt for his animal foods, although conservation of our natural game and fisheries resources is being studied and practiced. Our major food animals are selected, bred, fed, slaughtered, and transported under conditions which are constantly being improved by extensive research. Research helps to determine not only what foods should be fed to produce more meat per pound of food, but how and when it should be fed to produce the highest quality of beef,

[1] HANNAN, The Influence of Weather on Crops, 1900–1930, U. S. Dept. Agr., *Misc. Pub.* 118, 1931. A selected and annotated bibliography.

pork, poultry, milk, or eggs as the case may be. Our fisheries are subject to investigation and research to determine better policies concerning what might be termed our farming under the sea.

The handling of this great volume of food supplies and the making of food products therefrom is a problem of primary magnitude in the welfare of the nation and is of ultimate concern to every person dependent on these supplies for sustenance. The problems in this field of endeavor are numberless but are being gradually solved. The worlds of science and those of industry and finance have labored toward the ultimate goal of utilizing these food products of the soil and sun, with a minimum of loss due to spoilage or waste and a maximum of benefit to the consumer from the standpoint of economy, nutriment, health, and utility.

The biologist, chemist, physicist, engineer, and sanitarian all have made and are continuing to make contributions to such scientific endeavors. Some of the problems are being solved by unlocking the chambers of doubt or ignorance by the keys of exact scientific information, but there are many locks yet to be opened. Many technological methods of food handling according to older habits or customs have fallen by the wayside when weighed on the balance of strict scientific investigation. New food products have been developed and many new food sources tapped. Procedures and uses have been made available for the by-products associated with certain food materials. Much effort has been directed toward increasing our knowledge concerning the types of materials which may be harvested from the sea as well as conserving foods from this source which we now enjoy.

In the past three decades there has developed an increasing diversity in the diet of the average American, owing in part to the easier availability of foodstuffs of a wider variety. The perishable commodities of the past century which were available for only a brief period each year in locations close to the source of supply may now be obtained at almost any season whether produced nearby or at the ends of the earth. Many factors have combined to favor this widening of the horizons of food supplies and food products. Faster and more dependable transportation, improvements in refrigeration and other types of preservation, and increased knowledge in the technology of foods have each played an important part.

The changing habits of the present generation have had their influence on the production of foods also, because our urban inhabitants have come to prefer many of their foods in a prepared or partially prepared condition in order to lessen those duties in the home which were entailed in preparation. The modern breakfast table is likely to have its toast which is made from bread baked in large city bakeries; fruit juice from orchards a thousand or more miles away; breakfast foods prepared and packaged in the corn belt; coffee roasted and ground hundreds of miles away; cream or

milk from large dairies in distant counties or states; and sugar from the far-off beet fields or tropical plantations which has been refined and packaged in some city plant many hours away. Even the eggs may have arrived promptly, after a refrigerated ride in a transcontinental express freight, with the ability to demonstrate the pristine virtues of an egg hardly cool from the nest. It is apparent that many regions of our own country and lands beyond our borders are commonly used as sources of food supply, just as many processes, much equipment, and manifold technical services are required to furnish the products of the modern table in their desired form and quality.

Some 359 millions of acres in the United States were reported to have been harvested according to the census of 1930, which reflects the tremendous extent to which agriculture directly or indirectly assists in supplying our food needs, although coffee, tea, spices, and certain fruits are not raised in commercial quantities within our boundaries.[1] A vast army of workers is required, not only to plant, harvest, or raise the raw food materials, but also to transport, manufacture, merchandize, and deliver the products of these foods to the ultimate consumer. The harvested crop land in this country is estimated to constitute about 18.9 per cent of our land area, and in addition there are many more million acres available for pasturage purposes which serve as food supplies for food animals, as shown in Fig. 1.

It is less than three quarters of a century since the composition of food with reference to their components of protein, carbohydrates, and fat was at all clearly recognized, and the first real researches on foods were devoted to chemical studies on the composition of various food materials. A vast amount of work was bestowed on this aspect of food research in the last three decades of the nineteenth century and it is in general within that period that the great governmental laboratories of the leading European countries and in the United States were established for scientific control. While fundamental problems were in some degree considered, another aspect, namely, the examination of foods for adulterants, as a means of protecting the public against fraud as well as against possible harmful added substances, became one of the principal fields of food study, and with the improvement of the microscope this instrument added greatly to the facility of such investigations and to our knowledge of the structure of food materials.

Studies of most elaborate character on energy yield or fuel value soon followed knowledge of composition. The splendid work of Max Rubner and his disciples resulted in the widespread interest in calories and the

[1] Recent experiments by the Bureau of Plant Industry, U. S. Dept. Agr., have shown that coffee and cacao may be cultivated in southern Florida if the plants are given proper shelter. See O. F. Cook, *Science*, **83**, 56, 1936.

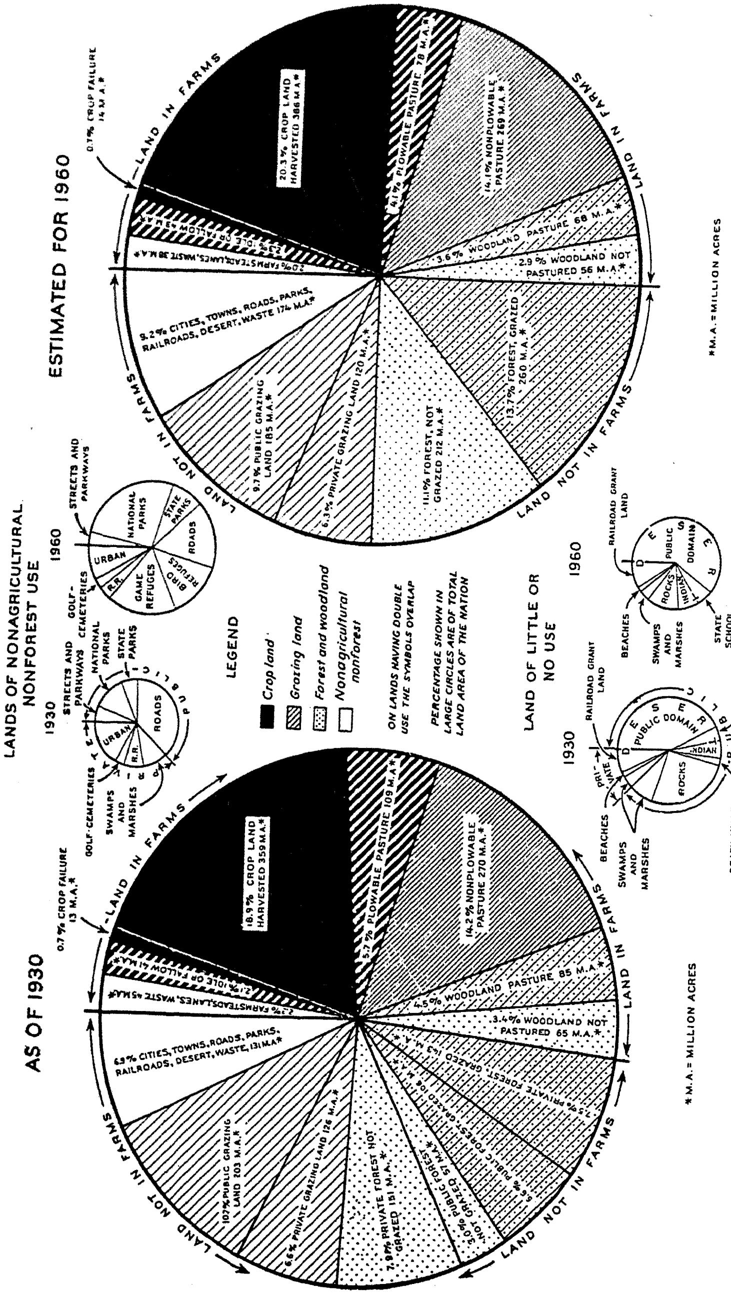


FIG. 1.—Major uses of land in the United States. (*U. S. Department of Agriculture.*)

energy values of foods. Rubner showed clearly how foods serve as fuels for the human machine. In this country epoch-making investigations were carried out by Professor Lusk and others, and the study of the food needs for workers in various kinds of occupations, such as those requiring great muscular effort on the one hand and the less exacting sedentary pursuits on the other, were carefully studied and evaluated. Thus was created an interest in calorific values and food requirements as expressed in diets of varying complexity. This interest had its peak about a generation ago, but it is still potent enough in its appeal to popular imagination to cause certain purveyors of food to tabulate calorific values on the menus which they provide their customers. It was soon found, however, that not all the recognized facts of nutrition could be explained solely on the basis of calorific value, for large numbers of cases were evident in which the total food intake was ample to supply the food requirements and yet the consumers were not necessarily well nourished nor did they continue in good health. Therefore further research was necessary to explain these matters and to find the causes of the deficient metabolism. One of the outcomes of this long and patient study was the discovery by Osborne and Mendel of the different essential types of amino acids derived from protein food which, when assimilated, may become the building blocks by which the structures of the body are continuously reconstructed and maintained, while at the same time the worn out material is being eliminated in the body wastes. Regardless of the number of calories which might be obtained by actual combustion, if, in the digestive cleavages of a protein food, the requisite types of amino acids are not all produced, the body does not obtain the full complement of structural materials. Furthermore, it became recognized that certain portions of the food, such as the fats and sugars and starches, were consumed largely to yield energy in the form of heat, while the proteins, on the other hand, supplied the material for structure and repair of the tissues. Thus the concept of a balanced ration was the direct result of research.

From the practical or commercial standpoint another line of food research was clearly recognized some forty years ago. From simple beginnings far in the past, great advances had already been made in the technique of food preservation by canning, drying, preserving, and even in refrigeration. There had also been enormous and unexplainable losses, for manufacturers did not know the underlying fundamental sciences. The problems of food spoilage and of maintenance of foods in good condition therefore became of vast importance, and especially so with urban development, higher living standards, and growing industrial life. Here was an economic problem of prime significance, and the attack thereon opened up vast fields of food research which has been of immense commercial significance and greatly enriched our knowledge. Without

keeping in mind the advances of science it is difficult to visualize the methods or understand the opinions and attitudes of 50 years ago. Through years of hard experience and empirical trial and error, a good but inexact practical knowledge of the effect of cold and heat, of the use of spices and sugar as preservatives, and of drying, pickling, and smoking, had come down from a remote past. The reasons were unknown—why could the Indians in the hot dry Southwest preserve buffalo meat by simply hanging the strips of it in the sun? Why could the colonial housewife preserve blueberries by use of cloves and other spices, or wild strawberries with sugar? Why did corned beef or salt pork keep for months until used? It remained for the real scientific research in the last few decades to explain why these processes were possible and to put them on a successful basis. Thus, while the rule of thumb experiments of Appert in France and of Saddington in England early in the nineteenth century laid the foundations of the canning industry, it was not until after bacteria were known as living things, and the application of the more exact knowledge of microbe life had begun to be elucidated by Pasteur, in the sixties of the last century, that the fundamental causes of food decomposition even began to be made clear. It was also Pasteur who, in his long and scrupulously careful studies on the causes of deterioration in wines found that by use of a temperature of 158°F. maintained for 15 to 30 min. he could prevent wines from becoming sour, turbid, and useless, while if not heated they would have been a total loss. No doubt the practice of scalding certain fluids in order to lengthen their keeping time had been employed long before his era. But it was his research that gave this process definite characteristics and transformed a haphazard and mysterious action into the application of a fundamental principle based on definite data. Thus pasteurization was evolved. The importance of this piece of careful observation and experiment, viewed in the light of its subsequent application to milk supply, is of untold magnitude, for it has been one of the greatest factors in the conquest of disease and the promotion of public health.

Not until bacteriology was studied in its specific relation to the different branches of the food industry itself could their processes become established on a commercially and scientifically sound basis. In most food industries this did not take place until the nineties or later.

Hand in hand with the progress of bacteriology and its applications in the food industries has come increased usage of chemistry and other sciences which has resulted in improvements of methods and new food products. Engineering has made possible the handling of food products more efficiently and eliminated many of the inefficiencies of small-scale food production. The use of by-products in larger food organizations such as the packing houses is a notable example in this respect. Refrig-

eration by mechanical means has made possible the utilization of many products which would otherwise be unknown because of the barriers of time or distance and has given rise to the new quick-freezing industry.

The chemical engineer has opened wide vistas in the use of edible oils by the conversion of such substances to solid fats by hydrogenation, enabling usage of the plant products of the tropics as sources of materials for the tables of cooler countries. The development of carbon dioxide which Priestley described a hundred years ago has only come into its own within the past decade with the production of solid carbon dioxide. This product has many uses as a refrigerant and has become a factor in refrigerated transportation because it has the additional ability of restraining spoilage due to some types of microorganisms, thereby extending the storage periods of certain foods.

The development of electricity is intimately related with all food production. Fertilizers for our food plants may now be obtained by electrical methods, using nitrogen from the air instead of importing nitrates from Chile or equally distant deposits. The progress of electrical engineering has been intimately connected with food production in many ways. Electricity turns the wheels of our food factories, lights our buildings, may propel our trains and trucks. It is used to irradiate hens for higher egg production, and ultraviolet lamps may be used to build up the vitamin D content of milk. Artificial light may be used to stimulate the growth of plants in scientific horticulture, and certain wavelengths, either from the sun or from artificial lamps, can increase or shorten the latent period of certain seeds at the will of the planter.

It would be impossible and likewise impractical to attempt an evaluation of all the various scientific factors concerned in food technology and its development, but in the modern food industries a combination of the efforts of thousands of workers over many years has made possible the present status of processes now used. Improvements are being made daily, certain mechanisms and methods continually becoming obsolete in the light of changing conditions. The modern methods of today will be discarded tomorrow when more is learned concerning foods and the way in which they may be made better, more appealing to the public, safer, more efficiently, or more cheaply as the case may be.

The economics of food supply and food products present many broad fields for scientific and technologic research and application. The most efficient choice and utilization of land for the raising of particular food crops, the conservation for food purposes of land which is now wasted, proper crop rotation and fertilization, seed selection, plant and animal breeding, control of disease in crops and animals, prevention of spoilage, control of insect depredations, all afford problems worthy of greater attention.

The storage, transportation, refrigeration, and preservation of foods in their natural form and food products made therefrom, the elimination of deleterious changes due to enzymes or microorganisms, the more efficient utilization of by-products, the proper utilization of foods in the dietary—each presents challenges to science and the student of foods who has a scientific training.[1]

The individual who makes his decision to enter the food industries and food research will never lack for problems as they are manifold. New difficulties and means by which they may be surmounted are constantly appearing. In some instances the solution may be found in the basic methods or knowledge of another food industry handling different materials yet having the same fundamental problems. Thus a broad insight in varying technologic processes often serves as a useful foundation for more specialized applications in specific fields. From this standpoint, food technology in its varying aspects affords ample opportunities for the study, research, and development of food processes, techniques, and products. Such endeavors may at times require the specialized training of the well-grounded biologist, chemist, engineer, physicist, or other scientist. Many times the endeavors are more likely to be solved by persons who have the viewpoint obtained from an intimate knowledge of several sciences and it is the person with the ability to bring into play a sound knowledge of the interrelations of the knowledge of these various fields who is likely to be the worth-while food technologist of the future.

The logical procedure for a start in this direction, however, is to become familiar with the manner in which foods are harvested, transported, manufactured and prepared for use, why certain processes are utilized and how the methods are practiced; in other words, by familiarizing oneself with the food technology of the present day.

[1] LINCOLN, A. T., *Science*, **40**, 463, 1934.

CHAPTER II

WHEAT AND MILLING

WHEAT

Wheat is one of man's most ancient and highly respected food materials. There is reason to believe that prehistoric man was familiar with the virtues of wheat and similar grains as sources of food. That there were numerous varieties of wheat was recorded by one of the students of Plato in about 300 B.C. At this early period many of the varieties were known by names indicating the country of origin although distinct differences in physical characteristics such as size, shape and color were apparent. The generic name Triticum has been used for wheat more than two thousand years and may have its derivation in the Latin verb "tritere" meaning to thresh or to grind, as the name may have once related to all grains handled in this manner.

Many of the descriptions of wheat written in the period of the Roman Empire bear close resemblance to some varieties still in existance. Its climatic characteristics are well adapted to the Holy Lands and within the present century a variety of wild emmer, a reputed ancestor of our present cultivated wheat, was found growing on Mt. Hermon in Palestine. The many Biblical references to wheat and bread clearly indicate the importance of this grain and its cultivation to the people in those regions in that era. In many parts of the world wheat is held in equally high esteem today and constitutes a very significant portion of the dietary.

The wheat plant is capable of growing in regions of relatively low rainfall and likewise of surviving rather wide extremes of temperature. The period in the life cycle of the plant when the rain does occur is of particular importance and should be preferably during the earlier part of its development. Good crops are facilitated by a period of maturation consisting of sunny warm weather and the absence of rain. Such conditions favor the development of seed or kernel rather than straw and are inimical to the cereal rusts, fungus diseases which raise havoc in wet weather.

Those conditions favorable to growth are met in many widely separated parts of the world and range from the tropics to Norway at a 64° N. latitude, from sea level to some altitudes of 8,000 ft. or over, and from irrigated desert areas to the regions of high seasonal rainfall which are fortunately followed by dry warm weather.

Smith[1] indicates eight important wheat-growing regions which are as follows: (1) The plains of southern Russia and the Danube valley, (2) the country bordering the Mediterranean, (3) Northwestern Europe, (4) the central plains of the United States and Canada, (5) Columbia Basin of the United States, (6) Northwestern India, (7) Eastern Argentina, and (8) Southern Australia.

The cultivation of wheat as a food crop has apparently extended over countless centuries. The exact geographical origin of this most important food plant is not certain, although it has been cited as growing in China as early as 3000 B.C. The Old Testament refers to wheat and it appears evident that this plant was also an important food crop of the ancient Egyptians. Wheat is also said to have been found in the settlements of the early Swiss lake dwellers.

The importance of wheat has not diminished to any extent, for man still holds in highest esteem the bread which may be made from this widely grown plant. In this country wheat was grown on about 60 million acres of our farm lands from 1926–1930, and the crop during this period averaged over 850 million bushels annually. It has been estimated that nearly one-third of the farmers in the United States are engaged in growing wheat, and a considerable number of these farmers are entirely dependent on this crop for their livelihood. Exports of wheat have constituted a valuable portion of our international trade and for two decades, previous to 1931, more than 12 per cent of our total annual wheat production was exported. Both acreage and exports have been somewhat reduced since that time.

The production of wheat in the United States has been closely allied with the development of the country, as the westward movement of wheat production was coincidental with the development of roads, waterways and railroads which were needed to transport the wheat from the farm to the large cities and ports of the seaboard.

In Colonial days wheat was grown on most farms, harvested with a sickle and subsequently threshed by hand with a flail, or by driving animals in a circular path through the sheaves to separate the kernels. The same primitive methods existed into the early part of the past century when the cradle was invented, which enabled the scythe-cut wheat to be deposited in rows. Cyrus McCormick invented the reaper in 1851, thereby making it possible to cut the mature wheat and drop it in bundles ready to be tied. This reaper led to other mechanical improvements which cut labor requirements and made it possible to produce wheat in larger acreage with the same man power. The thresher, which separated grain from the straw, was eventually united with the harvester. The modern "combine," harvester and thresher combined,

[1] SMITH, J. R., The World's Food Resources, 1919.

may cut and thresh all the wheat on a hundred or more acres a day. The primitive horse-drawn reaper of McCormick's day has given way to the tractor combine units which require relatively few men and need no horses which must be fed each day of the year. In 1923 almost 20,000 combines were sold in the United States.

Statistical data of wheat production in various countries since the World War (Table 1) indicate that Russia, United States, Canada, India, France, Italy, Argentina, Germany, Australia, and Spain are the leading wheat producers. The supremacy formerly held by this country in wheat production appears to have been won by Russia which reported a production in 1933–1934 of over a billion bushels. Since the bumper U. S. crop of 1931–1932 which amounted to over 900 million bushels, the

TABLE 1.—WHEAT PRODUCTION BY COUNTRIES (1921–1935)*
(1,000 Bu.)

Country	Average 1921–1922 to 1925–1926	1931–1932	1932–1933	1933–1934	1934–1935
North America:					
Canada	366,483	321,325	443,061	269,729	275,252
United States	786,866	932,221	745,788	528,975	496,469
Mexico	10,226	16,226	9,658	12,122	10,104
Europe:					
U. S. S. R.	457,857	753,238	744,052	1,018,893	
France	290,774	264,117	333,524	362,330	332,000
Italy	198,307	244,415	276,922	297,987	232,687
Spain	142,420	134,427	184,207	138,235	180,042
Germany	98,714	155,546	183,830	205,920	166,541
Rumania	89,570	135,300	55,537	119,072	77,315
Jugoslavia	58,753	98,789	53,444	96,584	68,328
Hungary	59,678	72,550	64,463	96,356	61,447
Poland	48,708	83,220	49,472	79,883	63,468
Africa:					
Morocco	21,758	29,783	27,970	28,902	31,232
Algeria	26,716	25,649	29,237	31,998	39,738
Tunis	7,892	13,963	17,453	9,186	15,800
Egypt	36,806	46,073	52,586	39,951	37,277
Asia:					
Turkey		104,946	71,135	99,636	88,546
India	336,271	347,424	336,896	352,763	349,365
Japanese Empire	37,171	39,931	39,936	49,263	54,420
Southern Hemisphere:					
Chile	25,761	21,187	26,114	35,307	
Argentina	203,388	219,696	240,889	286,120	252,059
Australia	128,520	190,612	213,927	175,370	137,000

* Yearbook of Agriculture, 1935.

production of wheat has decreased markedly (over 40 per cent in some years), owing in part to the most severe drought ever experienced in our Midwest and partly to the economic depression of the same period. The total world production is larger than that for prewar years despite unfavorable climatic and crop conditions in some regions. The assumption that no real world shortage of wheat is likely to occur for such reasons because of the widely separated regions of cultivation seems well founded.

For many years wheat was an important export crop of the United States and from one-fifth to one-third of all the wheat raised was shipped overseas for consumption in other countries. During the past decade there has been a decided decrease in our wheat exports, particularly in the past two years when less than 5 per cent was exported. Economic conditions, tariff changes, surplus crops from other large producing countries and our own reduced crops have all played a part in this decrease. The extreme changes in price which wheat has undergone in this country since the Civil War and the low prices during our recent depression years offer interesting comparisons (Table 2). In 1870

TABLE 2.—YIELD, PRICE, AND EXPORTS OF WHEAT PRODUCED IN THE UNITED STATES (1876–1934)*

Year	Average yield per acre, bu.	Production, 1,000 bu.	Price per bushel at Chicago, cts.	Per cent exported
1870	12.1	254,429	115	20.5
1880	13.2	502,257	99	37.5
1890	12.2	449,042	97	24.3
1900	12.2	599,315	72	36.8
1910	13.7	625,476	100	11.2
1920	13.5	843,277	216	37.1
1924	16.0	840,091	139	30.3
1925	12.8	669,142	161	13.8
1926	14.7	833,544	140	24.7
1927	14.7	874,733	138	21.8
1928	15.4	912,961	117	15.6
1929	13.0	822,180	130	17.1
1930	14.2	889,702	84	12.6
1931	16.3	932,221	53	13.3
1932	13.1	745,788	53	4.3
1933	11.0	528,975	94	4.8
1934	11.8	496,469		

* Yearbook of Agriculture, 1935.

wheat sold for an average of $1.15 a bushel, in 1920 for $2.16 and in 1931 and 1932, for 53 cents, with sometimes few buyers. The average yield per acre in the United States was approximately 5 bushels less in

1933 than in 1931 when over 16 bushels were produced, which gives evidence of the tremendous damage done by the drought.

Table 3 lists the more important wheat-producing states and their production in recent years in the order of their relative standing. The averages for 1927–1931 are fairly representative of the pre-drought period, with Kansas and North Dakota outstanding, followed by Nebraska, Oklahoma, Montana, Washington, Texas, and South Dakota. The decreases in yields of some of these states in 1933 and 1934 show the marked changes which climatic and economic upsets may exert on agriculture. Thousands of acres of land once used for wheat have been permanently eliminated as far as wheat production is concerned but in spite of these losses it appears that with normal weather conditions no wheat imports are necessary to meet the requirement of our nation.

TABLE 3.—WHEAT PRODUCTION IN THE UNITED STATES BY LEADING STATES*
(1,000 bu.)

State	Average 1927–1931	State	1933	State	1934
Kansas	176,235	North Dakota	72,115	Kansas	79,700
North Dakota	107,531	Kansas	57,504	Oklahoma	37,348
Nebraska	65,418	Washington	43,044	Washington	37,346
Oklahoma	52,641	Ohio	34,812	Ohio	33,401
Montana	50,388	Oklahoma	31,549	Indiana	32,151
Washington	45,345	Nebraska	29,206	Illinois	29,495
Texas	39,653	Illinois	27,418	Montana	28,174
South Dakota	36,466	Montana	26,480	Texas	25,749
Illinois	34,372	Indiana	22,905	Missouri	21,281
Ohio	29,673	Oregon	17,608	North Dakota	21,196
Indiana	27,626	Idaho	17,235	Idaho	18,696
Idaho	27,343	Missouri	16,989	Nebraska	15,838
Oregon	22,701	Minnesota	16,665	Pennsylvania	14,759
Minnesota	20,974	Pennsylvania	15,783	Oregon	12,944
Missouri	20,374	Texas	14,008	Minnesota	12,534

* Yearbook of Agriculture, 1935.

Biological Description and Classification.

Wheat belongs to the grass family, Poaceae (Gramineae), and to the tribe Hordeae, in which the one- to eight-flowered spikelets are sessile and alternate on opposite sides of the rachis, forming a true spike. Wheat is located in the subtribe Triticeae and in the genus *Triticum*, where the solitary two- to many-flowered spikelets are placed sidewise against the curved channeled joints of the rachis.

There are two sections of the genus *Triticum*, one including the old genus *Aegilops*, in which the glumes are flat or rounded on the back, and the other including *Sitopyrus*, in which the glumes are sharply keeled. All cultivated forms are found in the latter.

Wheat is characterized as a mid-tall annual grass with flat blades and a terminal spike. The spikelets are solitary, one- to five-flowered, sessile, arranged alternately on the nodes of a zigzag, channeled, articulate rachis; the rachilla of the spikelets disarticulating above the glumes and between the florets, or continuous; the glumes keeled, rigid, three- to several-nerved, obtuse, acute, or acuminate; the lemmas keeled or rounded on the back, many-nerved, ending in a single tooth or awn.[1]

There are almost infinite varieties of wheat which have been named and described. As early as 55 A.D., Columella described three types of *Triticum* and four types of bearded wheat, spelt, or emmer. Linnaeus, in 1753, established the first scientific classification of wheat, since which time numerous changes and additions by workers in every country resulted in rather confused nomenclature. There are now 230 standard varieties and 43 improved varieties registered in the United States which have been established through the studies of Clark and others of the U. S. Department of Agriculture.[2]

Numerous taxonomic characters are essential for the purposes of identification and description of wheat species and varieties, including the following: habit of growth, time of heading and ripening, height, stem color and strength, leaf character, spike characters, glume characters, awn characters and kernel characters. The major kernel characters are color, length and texture, although differences of the germ, crease, cheeks, and brush are also taken into consideration. In recent classifications of wheat species, chromosome numbers have also been used as a basis of classification.

The following key has been proposed by Clark and Bayles to the species of subspecies of wheat.[1]

1*a*. Chromosome number 21 in haploid division.
  2*a*. Terminal spikelets fertile; palea remaining entire at maturity; spikelets with 2 to 5 fertile florets.
    3*a*. Glumes shorter than the lemmas, firm; palea as long as the lemmas. (*Triticum sativum* Lam.)
      4*a*. Rachis tenacious; kernels separating from the chaff when threshed.
        5*a*. Glumes distinctly keeled only in the upper half; lemmas awnless or awns less than 10 cm. long; straw hollow.

[1] Clark, J. A., and B. B. Bayles, *U. S. Dept. Agr. Tech. Bull.* 459, 1935.
[2] For a detailed and complete discussion of wheat varieties see Clark, J. A., J. H. Martin, and C. R. Ball, *U. S. Dept. Agr. Bull.* 1074, 1922.

6*a*. Spikes usually long, dense to lax, somewhat dorsally compressed. (*T. aestivum* L., *T. vulgare* Vill.) .. COMMON WHEAT
6*b*. Spikes short, dense, laterally compressed. (*T. compactum* Host) .... CLUB WHEAT
4*b*. Rachis fragile; kernels enclosed in glumes when threshed.
5*b*. Spikes lax, narrow; pedicel long, wide, attached to face of spikelet below; shoulders wide, square. (*T. spelta* L.) .... SPELT
1*b*. Chromosome number 14 in haploid division.
2*a*. Terminal spikelets fertile; palea remaining entire at maturity; spikelets with 2 to 5 fertile florets.
3*a*. Glumes shorter than the lemmas, firm; palea as long as the lemmas. (*T. sativum* Lam.)
4*a*. Rachis tenacious; kernels separting from the chaff when threshed.
5*b*. Glumes sharply keeled at the base; lemmas usually awned; awns 10 to 20 cm. long; straw usually solid.
6*a*. Glumes and kernels short; kernels ovate, with truncate tips. (*T. turgidum* L.) .... POULARD WHEAT
6*b*. Glumes and kernels longer; kernels usually elliptical. (*T. durum* Desf.) .... DURUM WHEAT
4*b*. Rachis fragile; kernels enclosed in glumes when threshed.
5*a*. Spikes dense, laterally compressed; pedicel short, slender, usually attached to base of spikelet; shoulders wanting to narrow, usually oblique. (*T. dicoccum* Schrank) .... EMMER
3*b*. Glumes as long as or longer than the lemmas, papery, lanceolate; palea of lower flowers half as long as their lemmas. (*T. polonicum* L.) .... POLISH WHEAT
1*c*. Chromosome number 7 in haploid division.
2*b*. Terminal spikelets sterile, often scarcely visible; palea falling into 2 parts at maturity; spikelets usually with only 1 fertile floret.
3*a*. (*T. monococcum* L.) .... EINKORN

Of the species or subspecies listed above, common wheat (*Triticum aestivum* Linnaeus, or *Triticum vulgare* Villars) is the most widely grown and utilized and comprises 201 of the United States varieties. Its popularity is based on the reputation of these varieties as raw materials for flour capable of making high quality bread. Club wheat is not so desirable for bread flour but is used for biscuit and pastry flour. Durum wheat is used to a considerable extent for the manufacture of macaroni and spaghetti. The others are of relatively minor importance from the standpoint of both production and use in this country.

Official Grain Standards.—The following definition of wheat is used for the purpose of official grain standards of the United States:

Wheat shall be any grain which, before the removal of dockage, consists of 50 per cent or more of wheat and not more than 10 per cent of other grains for which standards have been established under the provisions of the United States

Grain Standards Act, and which, after the removal of dockage, contains not more than 50 per cent of broken kernels of grain of any size. The term wheat in these standards shall not include emmer, spelt, einkorn, Polish wheat, and poulard wheat.

From an official standpoint wheat is separated into seven classes which are very carefully defined and used as a basis for commercial transactions. They are as follows:

Class I. Hard Red Spring Wheat.
- Subclass (*A*) Dark Northern Spring.
- (*B*) Northern Spring.
- (*C*) Red Spring.

Class II. Durum Wheat.
- Subclass (*A*) Hard Amber Durum.
- (*B*) Amber Durum.
- (*C*) Durum.

Class III. Red Durum.

Class IV. Hard Red Winter Wheat.
- Subclass (*A*) Dark Winter.
- (*B*) Hard Winter.
- (*C*) Yellow Hard Winter.

Class V. Soft Red Winter Wheat.
- Subclass (*A*) Red Winter.
- (*B*) Western Red.

Class VI. White Wheat.
- Subclass (*A*) Hard White.
- (*B*) Soft White.
- (*C*) White Club.
- (*D*) Western White.

Class VII. Mixed Wheat.

The foregoing definitions indicate that one basis of differentiation used in wheat depends on its cultivation, namely, whether it is winter wheat or spring wheat. Winter wheat is planted in the fall, stays in the ground all winter and is harvested early in the following summer. Spring wheat is planted as early as possible when the ground can be worked and is harvested during the latter part of the summer.

In 1929 it was estimated that 43.5 per cent of the wheat acreage of the United States was planted with hard red winter wheat, 22 per cent with hard red spring wheat, 17.7 per cent with soft red winter wheat, 9.4 per cent with Durum, and 7.4 per cent with white wheat.[1]

Hard red winter wheat is grown principally in the south central and north central states and is the most important class raised in Iowa, Nebraska, Kansas, Oklahoma, Texas, Colorado, New Mexico, and Utah. Three most important varieties are Turkey, Black Hull, and Kanred.

[1] CLARK J. A., and K. S. QUISENBERRY, *U. S. Dept. Agr. Circ.* 283, 1933.

Hard red spring wheat is the class planted principally in Wisconsin, Minnesota, the Dakotas, Montana, and Wyoming. The most important

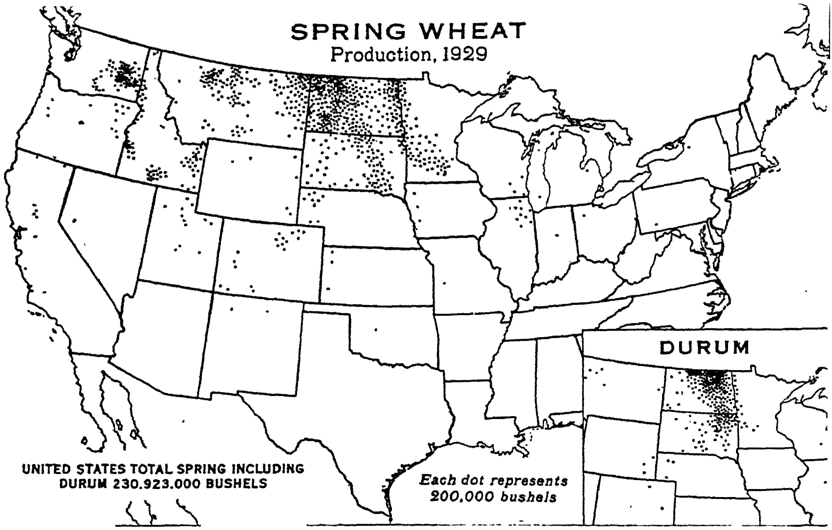


FIG. 2.—(*U. S. Department of Agriculture.*)

varieties grown are Marquis, Cereo, Supreme, Preston, Kota, and Ruby. Marquis made up 87 per cent in 1929.

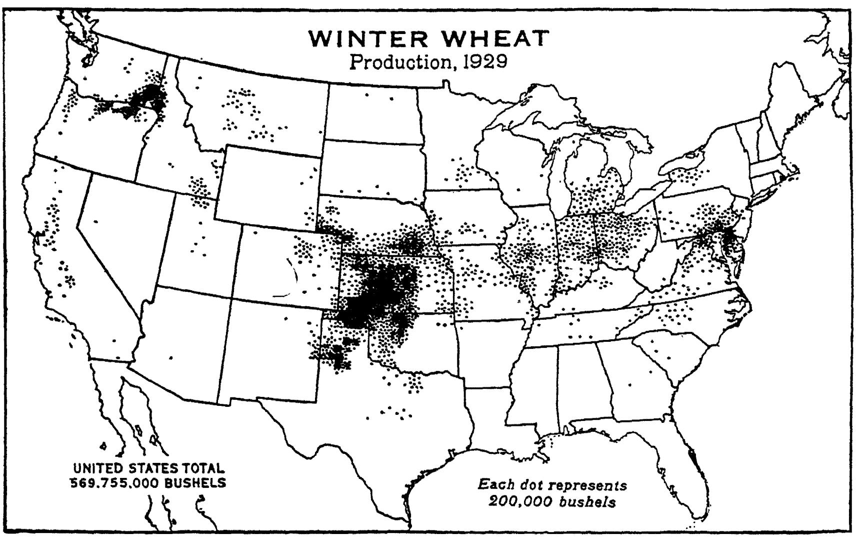


FIG. 3.—(*U. S. Department of Agriculture.*)

Soft red winter wheat was the leading class of wheat in 20 states and was grown in 28 states. The largest acreages were in Ohio, Missouri,

Indiana, Illinois, and Pennsylvania. The leading varieties were Fultz, Fulcaster, and Trumbell.

Durum wheat was produced on more than one-third of the acreage of both the Dakotas where it was the leading class in 1929. Other important Durum-producing states were Minnesota, Nebraska, Texas, Montana, Wyoming, and Colorado. The principal varieties grown are Pentad, Kubanka, Mindum.

White wheat is grown chiefly in the far west, Washington, Idaho, Oregon, and California having the largest acreages.

Gold coin, Baart, and Federation were the most grown varieties in 1929.

Structure and Development.—The cultivated varieties of wheat differ markedly in structure, habits, and appearance, although all are annual grasses which are composed of roots, culms, leaves, and spikes. The first set of roots formed are known as the seminal or seed roots, which are followed by the permanent or coronal roots. The latter are developed from the crown of the stem which is usually located just below the surface of the soil. Other structures of the wheat plant include the culm, a hollow, jointed cylinder comprising 3 to 6 nodes and internodes; the leaves, which are composed of sheath, blade, ligule, and auricle; the spike, which is made up of the rachis and spikelets and is borne by the peduncle, the upper internode of the culm. The spikelets are in turn composed of the rachillas, glumes, lemmas, paleas and the three stamens and the single ovary with its style and stigma.

When the wheat kernels are planted, they first undergo a germination period during which chemical changes are taking place in the seed, owing to the action of the vital processes which are largely enzymic in character. The germination activities require certain essential chemical and physical conditions, namely, moisture, warmth, and oxygen. The period of germination is considered as the time previous to the time when the stores of the mother plant are exhausted and the new young plant is entirely dependent on its own resources. The temperature relations during germination are particularly important as, in general, the higher the temperature, within limits, the shorter is the germination time. During this same process the germinating seed absorbs several times its own weight of water, without which the processes cease. Metabolic processes are utilizing a part of the chemical components of the kernel during germination so that as much as 10 per cent of the original weight may be lost in one week. As these same phenomena may occur if wheat becomes wet in storage, even though it is not planted, the importance of keeping wheat dry is apparent.

After the plant has developed roots, the subsequent growth of the plant depends on the availability of sufficient moisture, nutriments

suitable for conversion into plant tissues, proper temperature, and sunlight. The wheat plant is capable of standing the winter weather of many climates but growth during such periods is retarded and in many cases practically ceases until the advent of warmer weather. Winter snows act as a protection under such circumstances, but in very severe winters there may be killing of the plants owing to cold.

The roots may penetrate several feet into the soil, depending in part on the variety but more in respect to the soil, those in dry soil usually

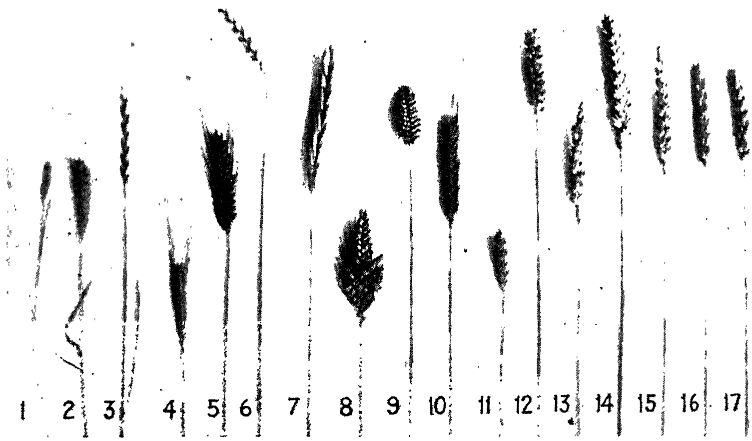


FIG. 4.—Types of wheat and grasses.

1, 2, 3. Wild grasses related to wheat
4. Einkorn, a one-grained wheat; not cultivated to any extent
5. Emmer, two-grained spelt, grown slightly in Europe and U. S.
6. Spelt, grown to a limited extent in Spain
7. Polish wheat, used some in Spain, Italy, and Abyssinia
8. Poulard wheat
9. Club wheat
10. Durum wheat, used for macaroni
11. Turney wheat, hard winter wheat of U. S.
12. Wilhelmina, soft, white wheat from Holland
13. Pacific Bluestem, soft, white, spring wheat of West coast
14. Dicklow, a soft spring wheat from Idaho and Utah
15. Marquis, hard red spring wheat
16. Red Fife, hard spring wheat of Great Plains region
17. Kitchener, a Canadian hard spring wheat

(*Taken from a publication on wheat. Field Museum of Natural History, Chicago, Ill.*, 1922.)

going deeper. Rainy weather is likely to cause shallow roots if it comes early in the growing season.

The height of the plant is likely to vary considerably and depends in part on where the wheat is grown. In general, wheat is considered tall if it grows much over 3 ft., although it may grow up to 5 ft. in some areas and as low as 12 to 20 in. The higher wheat grows, the more important the strength of its stem becomes, because with high stems and weak stalks "lodging," the bending or breaking of the stems, is likely to occur in wet or windy weather. This causes a serious economic problem from the standpoint of properly drying the grain and harvesting it.

Wheat Rusts.—During the growing season the wheat plants are subject to the devastating action of fungus parasites which are especially favored by excessive moisture. The wheat plant is host to the following parasitic fungi:

1. Stem rust—*Puccinia graminis tritici.*
2. Leaf rust—*Puccinia triticina.*
3. Stripe rust—*Puccinia glumarum.*

These moldlike fungi each have definite life cycles, produce millions of spores which infect not only wheat but also other plants and grasses, and cause tremendous economic losses because they cause low yields, injure the plants and the resulting cereal grain.

The majority of these fungi have intermediate hosts, other plants such as the barberry and the buckthorn. The control of these diseases is most difficult and no means of entire prevention is available. The elimination of intermediate hosts, the development of rust-resistant wheats, and the use of fungicides and seed treatment have been helpful in reducing the incidence and extent of such damage, however.

Stem rust is particularly destructive in the spring-wheat areas of eastern Montana, North and South Dakota and Minnesota.[1] Leaf rust is of greatest importance in the wheat areas of the Ohio and Mississippi Valleys and in the southeastern states. Stripe rust is confined to our Western states, and may be controlled by planting only resistant varieties. Warm and damp weather favor the stem and leaf rusts, whereas the stripe rust seems to thrive at lower temperatures.

Insect Enemies.—Certain insect pests are also capable of causing great damage to wheat crops if they are not controlled. One of the most serious of these is the Hessian fly (*Phytophaga destructor* Say) which is prevalent in the winter-wheat region. Others which are destructive at times are the cinch bug (*Blissus leucopterus* Say), the army worm (*Cirphis unipuncta* Haw.), cutworms, and grasshoppers (*Melanoplus spp.*).[2] The control of these insects, except the Hessian fly, is aided by the use of insecticides which to be successful must be carried out early in the infestation period. The Hessian fly is more difficult to control and requires special treatment. In bad infestations the crop must be plowed under to prevent spread to wider areas.

Handling after Harvest.—The harvested wheat is generally taken in bulk in wagons or trucks from the fields to a suitable dry-storage place, which may be the farm granary, the grain elevator, or temporary bins adjacent to the harvest fields. It has been a common practice in the Pacific Coast states to bag the grain at the threshing machine, although this method is more expensive, as handling the grain in bulk saves time

[1] HUMPHREY, H. B. and others, *U. S. Dept. Agr. Circ.* 341, 1935.

[2] *U. S. Dept. Agr. Farmers' Bull.* 835, 1935.

and labor in handling, eliminates the cost of bags, prevents waste from leaky bags and allows larger amounts of storage in the same cubic storage space.

The efficient handling of wheat demands the use of elevators which can carry the grain mechanically to a considerable height, from which it may be distributed by gravity to various bins and containers according to variety and quality. Portable elevators are sometimes used for handling grain to and from farm storage. Along the railroads and in large wheat centers there are hundreds of permanent grain elevators some of which are able to transfer thousands of bushels of wheat per hour.

Once the wheat has been harvested it is essential that it be protected against harmful influences, particularly those of excessive moisture and

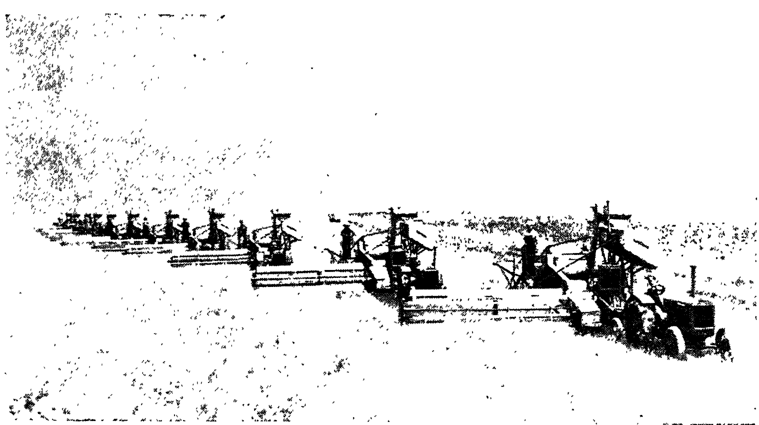


FIG. 5.—Modern wheat harvesting. (*Food Industries.*)

temperature. These two factors are intimately related because it is known that the tissues of wheat kernels undergo respiratory processes after the wheat has been harvested. The rate of respiration is increased when the wheat is damp, and because of the increased respiratory rate the temperature of large quantities of stored wheat in a confined space is raised. It is generally considered that a moisture content of more than 14.5 per cent is dangerous.[1]

Increased temperature and moisture also favor the growth of microorganisms on the surface of the grains, and assist in lowering the quality of the wheat. An hypothesis advanced by Bailey to account for the increased rate of respiration which occurs in grain with high moisture content suggested that the higher moisture content enabled the colloidal content of the grain cells to become a gel with continuous structure, thus

[1] BAILEY, C. H., The Chemistry of Wheat Flour, 1925.

enabling more rapid diffusion of the products of metabolism, or an acceleration of enzymatic action.

The embryo or germ of the wheat is the most important part of the kernel from the standpoint of changes in respiratory rate. A small amount of sweating, a term used to designate a slight accumulation of moisture on wheat due to respiratory processes, is considered a normal part of the life cycle of wheat and is said to have a beneficial action from the standpoint of the baking qualities of the flour made subsequently. However, it must be properly controlled for the higher moisture and temperature conditions may be disastrous. Overheated wheat is likely to be discolored and produces flour of lower baking quality.

Although the wheat which arrives at the grain elevator has already been partially cleaned by the thresher, it usually is not one hundred per cent wheat because of the presence of varying amounts of foreign matter other than whole, sound wheat kernels. This foreign material, called dockage, may be grouped in two large classes, foul dockage and smut dockage. The Federal grain standards set very definite methods for determining the amount of dockage and include under foul dockage sand, dirt, weed seeds, weed stems, chaff, straw, grain other than wheat, and any other foreign material which can be removed readily by the use of appropriate sieves, cleaning devices or other practical means.

Wheat raised on semiarid lands, particularly in the Pacific Northwest, is subject to a serious disease known as bunt, or stinking smut, a fungus growth which infests the growing grain, and causes each infected kernel to become a ball of fine dustlike spores, which are difficultly separated from the good wheat kernels. Some of these balls are soft and break in the normal handling processes, releasing billions of dark colored spores which give the wheat a dingy black appearance, while others are hard and vary little in physical characteristics from the good wheat. The smut dockage due to these causes results in a tremendous loss to wheat growers, because of reduction in crop yield, expense in cleaning the smutty wheat, and the expense of transportation of this foreign material along with the wheat until it is separated. It is estimated that the annual loss from this cause in Washington, Oregon, and Idaho is more than 7 million dollars. Precautions should be taken to treat seed wheat of this nature with fungicides before planting to avoid infestation of the crop as far as possible.

A campaign has been waged by agricultural authorities to clean the smut-infested wheat near the source of production to eliminate transportation charges on the worthless grains which must ultimately be discarded.[1] When the dockage is removed on the farm or at the country grain elevator, it can be utilized by the farmer as feed for livestock and

[1] *U. S. Dept. Agr. Misc. Circ.* 56, 1926.

therefore is not an entire loss. Cleaned wheat is more valuable than dirty wheat, and the producer gets more for the thoroughly cleaned wheat from a given acreage, in spite of a lowered volume in bushels, than if the dockage were not carefully removed.

Of the dockage, weed seeds are the most troublesome. Spring wheat contains a greater percentage of weed seeds than winter wheat, principally for the reason that the season of maturity of spring wheat coincides for the most part with that of the weeds. The average dockage found at the Minnesota terminals for the period 1921–1925 (spring wheat) was slightly over 4 per cent. For some states this figure is much higher. Nearly 300 different kinds of weeds have been found in wheat fields. A few of the most important ones are wild oats, wild buckwheat, mustard, foxtail grass, corn cockle, wild vetch, kinghead, wild rose. Garlic and wild onions are found commonly in the areas where winter wheat is grown.

Unless removed, the general effect of these weeds is to lower the baking value of the wheat, because they favor a reduction in the volume of the final loaf, change the texture and color of the bread, and impart odors and flavors which are undesirable.

Cleaning.—There are two common methods for cleaning the wheat. The more widely used method is the general-purpose cleaning. This system consists of sieves and air currents. If the sieves are shaken in the direction that the air travels, the machine is known as an end-shake machine; if crosswise to the direction of the air, a side-shake machine. Air may be blown up or down through the wheat (termed air blast and air suction, respectively). Separation is brought about according to difference in length, diameter, shape, or specific gravity of the various seeds, etc.

The second method of cleaning employs special separators to remove cockles, wild peas, wild oats, kingheads, and the like. Sometimes dockage presents particular problems of separation which must be solved. This is the case when "smut balls" or garlic bulblets are mixed with the wheat. "Smut balls" and spores of bunt or stinking smut are removed either by washing the grain in water with special apparatus or by mixing the grain with finely ground and bolted air-slaked lime before the wheat is scoured. To remove the garlic bulblets it is customary to heat the grain and then blow air through it with an aspirator. The heating dries up the bulblets and they can then be easily removed.

The farmer, grain dealer, and elevator man sustain huge losses each year because of insect depredations in wheat. A survey in the state of Pennsylvania showed that the annual loss due to the grain moth in that state was more than a million dollars. This loss can be largely prevented by proper treatment applied as early as possible after the crop is harvested. The primary infestation usually takes place before the grain has

ripened, and any delays which may take place before the crop is put under cover and in bins where it may be treated offer opportunity for the insects already present to multiply and infect other kernels.

The most common and likewise most efficient method of treatment of such insects is by fumigation of the grain in an airtight bin or other container. The temperature should be not lower than 75°F. for best results and may be as high as 95°F. The chemicals most widely used as fumigants are heavier than air, which enables the gases to sink down through the grain in a bin, displacing the air which is of lower specific gravity, and kill all stages of the insects, including the adults between the kernels, the eggs already laid in the kernels, and the grubs, pupae, and adults which are in the kernels themselves.[1,2]

The following gases are among those used for this purpose: carbon disulphide, carbon tetrachloride, ethylene oxide, ethylene dichloride, and mixtures of these gases. Chloropicrin may also be utilized. Sulphur dioxide was formerly used but has been displaced by the chemicals mentioned above.

Carbon disulphide is a very efficient fumigant, but its use presents a fire hazard which limits its application when used alone. Carbon tetrachloride is frequently mixed with carbon disulphide to lessen the fire danger but the insecticidal efficiency is largely dependent on the proportion of carbon disulphide in the mixture. Ethylene dichloride, which is also inflammable, is used in mixture with carbon tetrachloride which renders the mixture noninflammable, although this mixture is not so efficient as carbon disulphide. Carbon tetrachloride alone may be used but it is estimated as being only 5 per cent as efficient as carbon disulphide.

Ethylene oxide is also inflammable in high concentrations, but is usually mixed with carbon dioxide which removes the fire hazard and also is said to accentuate the insecticidal power. It is reported that about seven parts of carbon dioxide to one part of ethylene oxide is very efficient when 2 lb. of ethylene oxide is used per 1,000 cu. ft. of space.

Hydrocyanic acid is a most effective fumigant for grain but is a deadly poison to man and should never be used without competent and trained persons in charge of the work. This gas is quite widely used as a ship fumigant, and is now generally mixed with 5 or 10 per cent of chloropicrin, which is one of the tear gases used in the late war. The lachrymatory gas is used as a warning to drive humans from the presence of the deadly hydrocyanic acid which itself has a characteristic but only rather faint odor.

Calcium cyanide may be used in powder form to dose wheat being conveyed into a bin so that hydrocyanic acid may be subsequently liberated

[1] BACK, E. A. and R. T. COTTON, *U. S. Dept. Agr. Farmers' Bull.* 1483, 1926.
[2] *U. S. Pub. Health Repts.*, No. 29, July, 1931.

and fumigate the grain. This method is attended with the same dangers.

None of these substances cause objectionable odors or baking characteristics if the chemicals used are of high grade. As far as is known, none of these chemicals have an injurious effect on the germination of grain, if used for seed, except ethylene oxide, which is therefore not recommended for treatment of seed grain.

Insects in stored wheat may also be practically eradicated by heating the grain to a temperature of 125 to 140°F., but wheat is usually sold by weight and such temperatures drive off moisture and so cause a loss to the owner. Consequently this method is not commonly used.

Cooling wheat to temperatures close to freezing will bring about a cessation of insect activities temporarily but the insects will renew their attack when higher temperatures are again reached.

The Wheat Kernel.—The wheat kernel consists of three main parts, the bran, the endosperm, and the germ or embryo. Bran is the tough, protective covering of the kernel, containing a small amount of protein and very little fat, but much fiber and mineral material. Bran constitutes about 5 per cent of the kernel by weight.

The bran may be divided into the outer and inner parts. The outer part consists of the cuticle, or epidermis of woody fiber, the epicarp, and the endocarp, all of which are distinct layers of cells. Just under the endocarp lies the inner part of the bran, known as the episperm or testa. Most of the coloring matter of the bran lies in the episperm.

Chemical Composition of Wheat.—Table 4, containing data concerning the chemical composition of wheat and other cereal grains, shows that in all these food materials the starch or carbohydrate portion is the largest single component. Despite this fact it is the protein content that gives wheat its supremacy as a food for man because the protein of most wheats enables the carbon dioxide gas produced during the panary fermentation to be trapped, thus leavening the loaf and making it more edible and desirable.

The limits of the various percentages indicate the rather wide variations which may occur in any one component of a single cereal. These differences in composition, as well as the quality of the components, are of great importance to the miller in selecting and blending wheats from various sources in order to obtain the desired quality and uniformity of his flour.

The endosperm consists of the aleurone layer, which lies directly under the bran, and the gluten and starch portion of the kernel. Cells in the aleurone layer contain fat, mineral matter, and protein. These cells constitute about 8 per cent of the weight of the kernel and are removed along

with the commercial by-products since they adhere to the bran in the milling process.

TABLE 4.—CHEMICAL COMPOSITION OF CEREAL GRAINS*

Grain	Moisture	Proteins	Ether extract	Crude fiber	Ash	Carbohydrates other than crude fiber
Wheat domestic:						
Maximum	14.53	17.15	2.50	3.72	2.35	76.05
Minimum	7.11	8.58	0.28	1.70	1.40	66.67
Mean	10.62	12.23	1.77	2.36	1.82	71.18
Wheat, foreign:						
Maximum	12.97	14.52	2.26	2.89	2.04	76.14
Minimum	8.52	8.58	0.73	1.87	1.67	67.01
Mean	11.47	12.08	1.78	2.28	1.73	70.66
Barley:						
Mean	6.47	11.52	2.67	3.81	2.87	72.66
Buckwheat:						
Mean	12.31	10.86	2.06	10.57	1.85	63.34
Corn, domestic:						
Maximum	12.32	11.55	5.06	2.00	1.55	75.07
Minimum	9.58	8.58	2.94	1.00	1.19	68.97
Mean	10.93	9.88	4.17	1.71	1.36	71.95
Oats, domestic:						
Maximum	13.02	15.05	6.14	16.65	4.37	61.44
Minimum	7.87	9.10	0.93	8.57	2.47	53.70
Mean	10.06	12.15	4.33	12.07	3.46	58.75
Rice:						
Unhulled	10.28	7.95	1.65	10.42	4.09	65.60
Unpolished	11.88	8.02	1.96	0.93	1.15	76.05
Polished	12.34	7.18	0.26	0.40	0.46	79.36
Rye, domestic:						
Maximum	11.45	18.99	2.30	2.50	2.41	75.36
Minimum	9.54	8.40	1.16	1.65	1.71	63.61
Mean	10.62	12.43	1.65	2.09	1.92	71.37

* Taken from LEACH, Food Inspection and Analysis, 9th ed., John Wiley & Sons, New York, 1920.

Since the endosperm, minus the aleurone layer, is fairly friable, it pulverizes easily between rollers. About 85 per cent of the kernel is made up of the endosperm, and it is from this portion of the kernel that the flour is made from wheat by passing it between sets of rolls in the milling process.

The germ contains most of the fat, with some nonglutenous protein and sugar. The germ is eliminated in the milling process because the presence of this fat tends to cause undesirable flavors and colors in the flour. The germ makes up approximately 2 per cent of the kernel by weight.

Some of the larger milling organizations have special field representatives who cover all the important American wheat-growing districts during the harvest seasons and collect representative samples from different varieties in each area. These samples are shipped to their laboratories, tested for chemical composition and baking qualities, and the results used as a guide for their purchasing agents in order to obtain the wheats best suited for their needs. The American wheat harvest generally takes several months, starting in May in the wheat fields of Texas and Oklahoma and progressing to the northward and westward until September when the grain in Northern Canada is harvested.

Wheat Markets.—The half billion or more bushels of wheat ordinarily required annually by millers must eventually reach markets where the miller or his agent can complete the transactions with the farmer, those to whom the farmer sells his wheat, or their agents.

No such specific place or organization where transactions on a large scale could be conducted was available until 1848 when the Chicago Board of Trade was founded for this purposes. For many years Chicago was considered the primary grain market of the world, owing in part to the facilities for storage, favorable geographic location from the standpoint of rail and water transportation, and its famous Wheat Pit maintained by the Board of Trade where the transactions were conducted. In 1930 Chicago was forced to relinquish her supremacy in this respect as for the first time her grain receipts were exceeded by those of Minneapolis.[1] As early as 1881 the wheat receipts of Minneapolis exceeded those of Chicago and in 1930 Kansas City surpassed Minneapolis. From 1920 to 1931 the average annual wheat receipts of Chicago amounted to over 40 million bushels and during the same period more oats and over twice that quantity of corn were received, indicating the importance of this city as a market for grain.

The 14 primary wheat markets in this country from 1920–1931 were Minneapolis, Kansas City, Duluth, Chicago, St. Louis, Milwaukee, Omaha, Peoria, Toledo, Detroit, Indianapolis, St. Joseph, Sioux City, and Wichita.

The transactions in grain markets like the Wheat Pit are aided by the establishment of strict rules concerning the conduct of the members, transactions of the exchange, and the standards set up for the materials sold. In this respect the grain standards are set up by the Grain Inspection Division, Bureau of Agricultural Economics of the U. S. Department of Agriculture, and all inspections are subject to their regulations, although the actual inspection is carried out by licensed inspectors paid by the exchange, except in cases of dispute.

[1] DUDDY and REVZAN. Univ. Chicago, Studies in Business Administration, **3**, No. 4, 1934.

In the grain markets it is possible to buy wheat which is on hand and also to deal in grain futures, which enables persons needing grain at some future time, such as a miller, to make negotiations at a stated price with some other party who agrees to deliver to him on a definite date the amount and quality of wheat he wants. The miller then may make contracts to sell flour at a stated price at some definite future period and be assured of his supply of wheat to make the flour, or in fact, he may agree to sell the flour and then make sure that he will have the grain to grind by purchasing futures. This type of transaction is known as hedging and is generally done as a means of protection, or insurance. It is possible to speculate on futures and huge fortunes have been made and also frequently lost by operators who have made promises to buy or to deliver wheat futures at definite prices. Unless the purchase or sale is counterbalanced, as is done in hedging, the market may undergo considerable price change in the meantime and the results may be disastrous to the operator who has not foreseen the changes accurately.[1]

In the Chicago Board of Trade, there are maintained a Corn Pit, an Oats Pit, a Rye Pit, and a Cotton Exchange on the same floor as the Wheat Pit. The unit in trade for wheat is 5,000 bu. and sometimes transactions amounting to millions of bushels are accomplished between the hours of 9:30 A.M. and 1:15 P.M., the trading hours.

MILLING

Development of Milling.—The primary importance of wheat is its utilization in the form of flour for the production of bread, man's most valued and honored foodstuff. The conversion of wheat into flour is likewise one of our most ancient food industries. Primitive peoples pounded wheat between rocks to make it more edible until this method was improved by the introduction of the more efficient rubbing or grinding technique which was similar in fashion to the use of mortar and pestle. The sifting of wheat particles so obtained in order to have a relatively fine meal for cooking purposes is said to have been practiced in the days of the ancient Egyptians. Rotary stones, one of which revolved upon the other that was stationary, were developed and operated by either animal or slave power before the Christian era. Such stones were later carved with radial grooves to allow the finely ground particles to be segregated and removed. Mills of this type were later improved and operated by water power, windmills, and subsequent to 1786 by steam engines. During the latter part of the nineteenth century metal rollers were substituted for the millstones and electricity has now come into wide usage for power to operate the modern flour mill.

[1] DIES, E. J., The Wheat Pit, 1925.

The earliest mill in America was built in Nova Scotia in 1605. When a few decades later the wheat crop of Virginia became of significant proportions, Richmond became the first milling center in this country and supplied not only local demands but exported some flour for the West Indies trade. As wheat growing extended inland, Rochester, New York, succeeded Richmond as the largest milling center and in turn was replaced by St. Louis. During the period prior to the Civil War winter wheat was the common type grown, but with the development in 1870 of the middlings purifier and the installation of the first roller mill in 1879, the harder textured spring wheat of our Northern States came into prominence for the making of fine flour. These inventions gave rise to the huge modern flour mills which almost entirely eliminated the smaller community grist mills of earlier years, and Minneapolis, close to the great wheat-producing areas, has become the largest flour-producing center in the world.

In 1933 there were approximately 2,000 establishments in the United States engaged in milling flour and other grain-mill products, employing some 30,000 people and manufacturing products valued at about 574 million dollars. The products produced in 1927 and 1929 in this country were valued at more than a billion dollars in each year. The wheat-flour production amounts to about a million barrels a year, of which over 90 per cent is white flour.

Processes Preliminary to Milling.—The various operations involved in the transformation of wheat into flour are largely mechanical in character and depend on a reduction in size of the components which make up the wheat kernel, with a subsequent separation of the particles according to size and composition.

Before these steps are taken, however, it is necessary to have the wheat thoroughly cleaned and all foreign material removed. Then it must be adjusted in physical characteristics so that the kernels are in optimum condition for the mechanical operations which follow.

The cleaning process is accomplished by means of separators, consisting of agitating screens and forced-air currents, usually followed by passing the grain through disk separators which complete the work. It is then scoured by friction or brush devices which rub off a portion of the outer coat and assist in removing the brush of the wheat and the closely adhering fine dirt which is found particularly along the crease. Scouring may be carried out before and sometimes also after the conditioning process described below.

It is also considered desirable by some millers to mix or blend different wheats in order to have certain characteristics in the flour which can be obtained only by the use of more than one variety of wheat, although

blending may also be accomplished by mixing the flour from various wheats after each has been milled separately.

Conditioning and Tempering.—Wheat is conditioned previous to milling in order to toughen the bran, making its subsequent separation from the flour easier when it is ground and bolted. The process consists of adding a certain amount of water to the already cleansed wheat and allowing the mixture to stand for a definite predetermined length of time. The period of time during which the grain is allowed to stay in contact with the water depends upon the initial moisture content of the wheat, the hardness of the wheat kernels, and the plumpness of the grain.

The less moisture the grain contains, the harder the kernel will be, as the plumpness is increased by additional moisture content. The amount of water and the time interval used are adjusted in order to give the best results in toughening the bran without simultaneously adding an excess to the endosperm. Only slight amounts of water are allowed to enter the endosperm, because if the endosperm is toughened, its constituents are inclined to flake between the rollers instead of pulverizing, hence involving losses in flour yield. The water may be added by a fine spray, by passing through a washer, the use of vapor dampened chambers, or by mixing with other wet wheat.

Tempering facilitates the milling operations which follow and tends to create a condition favorable to desirable enzymic reactions in the kernel; it may increase the flour yield. In some instances the temperature of the wheat is raised before the tempering period is started.

Breaking.—The first operation in the actual milling of wheat is called breaking, which is accomplished by passing the conditioned wheat between corrugated or grooved horizontal steel rollers. The rollers rotate in opposite directions and are geared so that one travels about 2½ times as fast as the other. The first break rolls are set sufficiently close together so the kernels are torn or crushed into relatively large particles, as this enables a better subsequent separation of the bran and the germ from the endosperm. All this material then goes to the first break scalper, where the larger particles are mechanically separated by size and returned to another set of rolls which are set closer together, the second break rolls, which also have more numerous corrugations to the inch than the previous set. Again the larger resulting particles are sent to a scalper, the second break scalper, and the fine particles composed largely of endosperm separated. The larger fragments go to a third set of break rolls and this process is repeated with further separations in the third break scalper. Any number of breaks up to about eight is possible, although the use of five breaks is more common.

The coarse fragments left from the final break constitute the bran, which is used for stock feeds and to a lesser extent as human breakfast

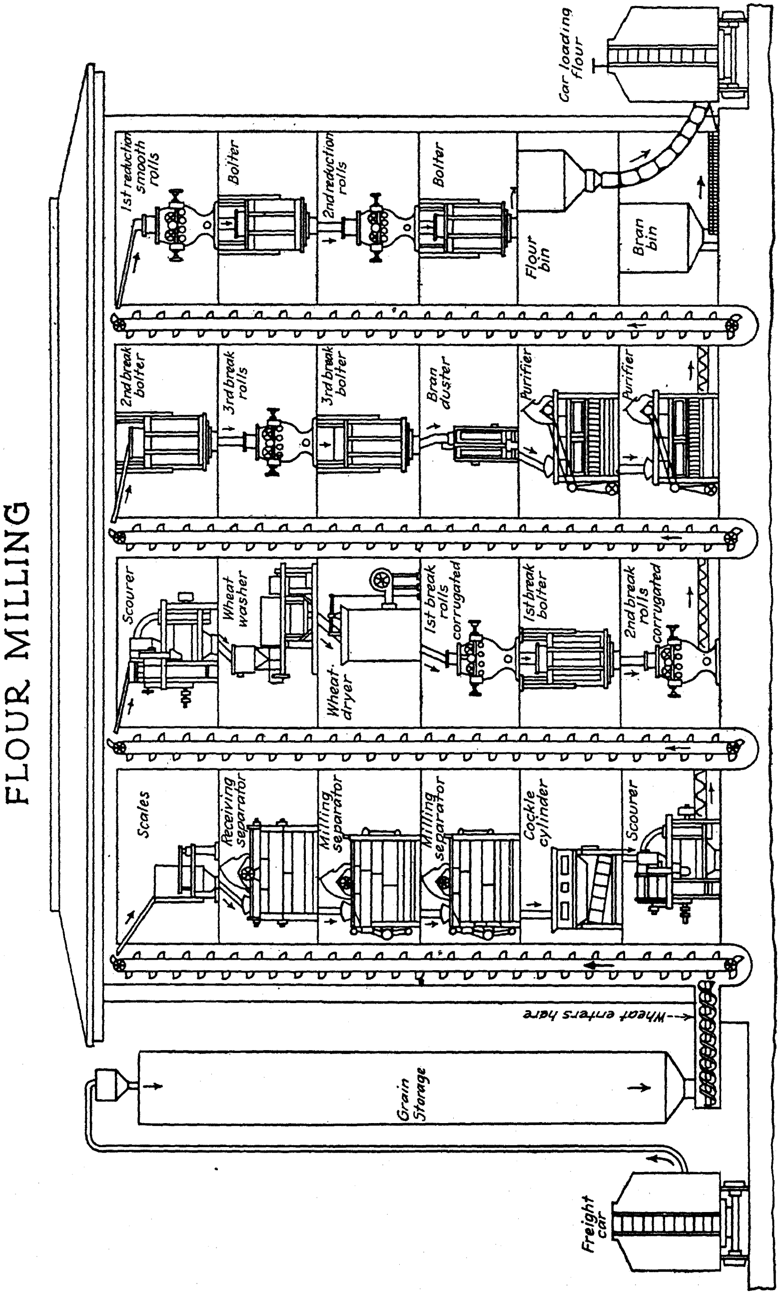


FIG. 6.—Flow sheet of flour milling processes. (*Food Industries.*)

food. This material is dusted to remove any adhering finer particles of endosperm and bagged or conveyed to a bin.

The other materials of smaller dimensions obtained from the breaks are known as the middlings and are the source of flour. If obtained directly from the breaks, the term break flour is used but an effort is made by all millers to keep this type of flour at a minimum because of its inferior quality.

The middlings, however, contain endosperm particles of various sizes too large to go through fine bolting cloth, mixed with small particles of

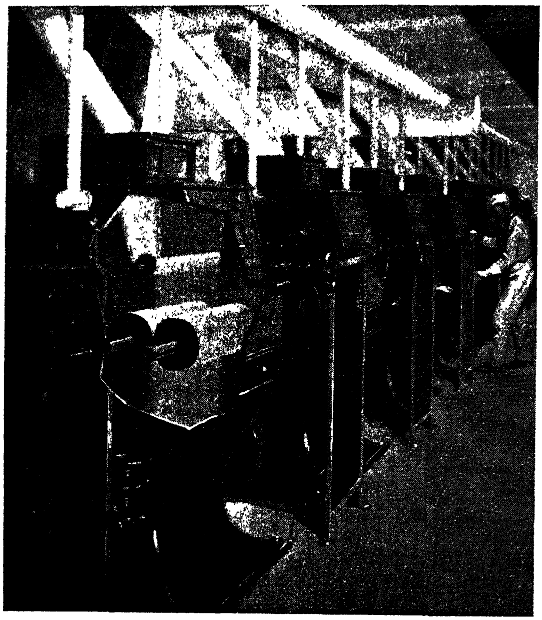


FIG. 7.—Grinding. (*General Mills.*)

bran, and the next process is the sifting of these particles and separation by size, followed by purification. This is accomplished by sifting in combination with the use of air currents of controlled velocity passing upward through the sieves so adjusted that the lighter, fluffy bran particles are removed, thus enabling the production of a more highly refined flour.

Reduction.—The middlings after passing through the purifiers consist of endosperm fragments separated into different sizes and practically free of large bran particles. In order to convert these fragments into flour they are subjected to further grinding into smaller particles, or reduction. The rollers used for this purpose are usually smooth in contrast to the corrugated break rolls and the ratio of rotation between

the rolls is reduced to one and a half to one. The setting of these rolls is also closer together than in the break rolls. After each rolling operation the crushed material is separated by means of sieves, the particles graded according to size and conveyed to subsequent sets of rolls set closer together and in the later reductions the material is subjected to pressure while passing between the rolls. This series of grindings between appropriately spaced rolls with the intervening separations enables a careful sorting of fine endosperm particles, the flour, from the remaining bran particles by means of reel bolters or flour dressers. During reduction coarse particles or sizings including the germ or embryo portion of

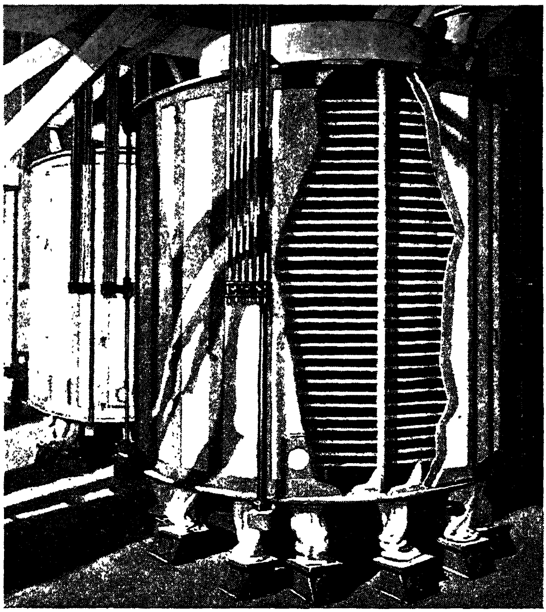


FIG. 8.—Bolting. (*General Mills.*)

the wheat kernel are separated. This material, which is relatively high in oil or fat content, is used for cattle food and to some extent in vitamin products for human consumption as it has been found to be a potent source of vitamins B, E, and G, as well as containing a fair amount of vitamin A. Unless the germ is carefully removed, the keeping quality of the resulting flour will be poor as the oil in the germ has a tendency to become rancid.

Materials containing larger quantities of bran may be sent to centrifugal reels, revolving horizontal cylinders which have mechanical beaters that force the finer particles through the silk bolting cloth which covers the cylinders.

Bleaching.—The flour obtained by these processes is generally somewhat colored owing to a number of possible causes, but it is essential that it be as nearly white as possible because of the prejudice of American consumers in this respect. Bran or other foreign materials such as dirt or weed seeds may accentuate color in flour, as do the natural yellow carotinoid pigments of wheat. The former may be largely avoided by care. Because of the latter, flour is often bleached by chemical processes to make it whiter. Carotin is capable of being oxidized and flour bleaching is an oxidation process. Unbleached flour in an atmosphere of hydrogen does not bleach, nor is it bleached to any extent if placed in a vacuum. Exposure in the air, however, especially in such a way that the particles are in intimate contact with the air, bleaches the flour readily, and the action is much more rapid if carried out in the direct rays of the sun. The bleaching process may be greatly accelerated by the use of certain chemical agents, however. In commercial practice the more common bleaching agents are nitrogen peroxide, chlorine, nitrosyl chloride, mixtures of chlorine and nitrosyl chloride, nitrogen trichloride, and organic peroxides, such as benzoyl peroxide. A number of such compounds are protected by patent for this specific purpose.

When the bleaching agent to be used is a gas, the gas is usually first mixed with air and then brought in contact with the flour particles in an agitator. Since each particle of flour must be bleached, it is necessary for the flour to be agitated in the gas or exposed as a very thin film. When the bleaching agent is a solid, it must be thoroughly mixed with the flour. This is done by mixing the flour and bleaching agent together in small quantities, using accurate measurements, and subsequently mixing this batch with large quantities of flour in a high-speed mixer.

It is possible to store flour for extended periods of time and obtain a considerable reduction in color, but many manufacturers prefer to use chemical agents which accelerate this process and cut down on the storage time necessary.

Methods have been devised recently whereby it is possible to decolorize flour pigments in bread dough by the use of enzymes from soybeans.[1,2] Small amounts of enzymatic materials are added when the dough is mixed and act during the usual dough-fermentation period. If such methods are adopted, the practice of chemical bleaching of the flour will be unnecessary.

Grading.—In the ordinary milling processes approximately 70 to 75 per cent of the cleaned wheat is converted into middlings yielding flours of different grades, and 25 to 30 per cent of the wheat into animal feeds. The exact methods of milling determine in part the proportions

[1] RUMSEY, *Food Ind.*, **2**, 57, 1930.
[2] VERON, *Food Ind.*, **2**, 59, 1930.

and types of products obtained as there are a number of grades of white flour, as well as other products such as "red dog" and "shorts" which are used for feeds.

The following definitions have been adopted by the U. S. Department of Agriculture for the most common flour products.

Flour, wheat flour, white flour, is the fine-ground product obtained in the commercial milling of wheat, and consists essentially of the starch and gluten of the endosperm. It contains not more than 15 per cent of moisture, not less than 1 per cent of nitrogen, not more than 1 per cent of ash, and not more than 0.5 per cent of fiber.

Whole-wheat flour, entire wheat flour, graham flour, is the product made by grinding wheat, and contains, in their natural proportions, all the constituents of the cleaned grain.

The grading of flour involves certain variables as there will be produced simultaneously in any mill a number of different flour streams from the usual operations, all of which vary somewhat from each other, although they come from the same wheat. The manner in which the different streams are combined or segregated determines the grade of the resulting product.

The highest grade, that having the least color and fiber, is called "patent flour." The term "clear" usually denotes those portions remaining after the patent is separated, except the "low grade" which is the last and lowest quality flour, not usually used for humans; this constitutes less than 5 per cent of the total.

It is obvious that the point where the miller limits the patent streams or proportions will determine the relative quality of this grade as well as the others. With high-quality patent, which may be from 40 to 70 per cent of all the flour, the term "fancy first" or "short patent" is sometimes used, but in contrast a long or second patent may constitute up to 90 per cent of the total, in which case the remaining clear flour is less highly refined. The term "straight" grade is generally used to denote a combination of patent and clear, while "standard patent" is used by some millers to denote all the patent and most of the clear. The clear grades may be further separated into "first clear" and "second clear," the latter being that remaining after separation of the former. Flours lower in grade than second clear, such as low grade and red dog are primarily used as stock feeds.

From the rather indefinite grade standards it is difficult to set any strictly defined standards for the chemical composition of the various grades of flour. After flour is milled, it "ages," and changes of a chemical character go on in storage. The humidity of storage conditions is definitely related to certain changes in flour on storage as flour is hygro-

scopic and may take on moisture. In a very dry atmosphere it may lose moisture. Federal standards allow up to 15.0 per cent moisture. Biological factors prevent much higher moisture contents in storage as microorganisms may grow and cause spoilage and so the miller avoids such conditions if possible. During storage there is an increase in acidity which is usually more rapid in the less highly refined flours and in those of higher moisture content. Temperature is also an important factor in this respect and warm storage temperatures for flour of high moisture content should be avoided.

These chemical changes during aging which are due to enzymes normally present in sound flour are considered desirable as the baking qualities are usually improved as a result; they give better volume, texture strength, and increased ability of water absorption. It is likely that during the process of aging the enzymes present in flour activate biochemical changes in the various components of flour, including the fats, the proteins, and possibly others, but the exact mechanism of these improvements due to storage is as yet uncertain. That increased hydrogen ion concentration is not the only factor concerned is clearly established, however.

Atwater and Bryant[1] give the following percentages as representative of the average composition of flour:

Water	Protein	Fat	Total carbohydrate including fiber	Ash
12	11.4	1.0	75.1	0.5

These figures would be subject to variation if one were to have flour made from separate varieties or classes of wheat and are more representative of the higher grades, as in the lower grades there is likely to be a higher ash content and a higher protein content.

From the baker's standpoint, the chemical composition of flour is of the utmost importance, particularly the protein content which must be considered in view of both its amount and quality. In general, the patent flours have a lower protein content but contain protein of much higher quality as shown in bakery tests.

The desired properties which are contributed by high-quality proteins are concerned with water-adsorption capacity, the subsequent yield of bread from a given amount of flour, the capacity of physical extension of the dough made therefrom and its ability to produce a final loaf of excellent texture and physical volume, provided sufficient gas is available during fermentation, according to Bailey (1925). The methods used in

[1] Atwater and Bryant, *U. S. Dept. Agr. Bull.* 28, 1906.

experimental milling and determination of the desired baking properties in the U. S. Department of Agriculture are described in detail by Shollenberger, Marshall, and Coleman.[1]

The proteins contained in wheat flour consist primarily of gluten, the substance which makes possible the tough elastic and rubbery character of the dough resulting from the addition of water to wheat flour. Gluten is not a definite chemical compound and is not entirely nitrogenous matter,[2] although it is spoken of as an entity. It is primarily composed of two groups of proteins: glutenin and gliadin. The former is a glutelin chemically as it is insoluble in alcohol but soluble in dilute acids and alkalies; gliadin is a prolamine being soluble in alcohol but insoluble in water. The glutenin imparts strength and cohesiveness or tenacity to the dough, whereas gliadin contributes its adhesive or sticky properties. These proteins are derived from the endosperm proteins but are mixed with the other constituents of the endosperm, starch, fat, and ash. Small quantities of proteins originating in the embryo may also be present in the flour.

Starch is the principal carbohydrate and makes up about three-fourths of the flour, but small amounts of lower carbohydrates, such as sucrose, invert sugar, and dextrin, may be present. The latter are derived from the embryonic tissues of the wheat.

The fat content of wheat may come from the endosperm which has a very low concentration, or from portions of the embryo or bran which are not removed. The embryo is much higher in fat content but is removed as far as possible in milling as its presence lowers the keeping qualities and may influence color.

The hydrogen ion concentration in wheat and flour usually ranges between pH 6.2 and 6.8.

Among the enzymes found in wheat flour are protease, tyrosinase, amylase, maltase, and peroxidase.

[1] *U. S. Dept. Agr. Bull.* 1187.

[2] Winton, Structure and Composition of Foods, 1932.

CHAPTER III

CORN AND CORN PRODUCTS

CORN (*Zea mays*)

The most important food crop of the United States, from the standpoint of both value and acreage is corn. It is probably the most valuable cereal crop of the American continent. The United States is the largest corn-producing country in the world, although it is estimated that more than 80 per cent of that produced never leaves the farm on which it is produced because corn attains its greatest usage as a food for the meat animals later consumed by man.

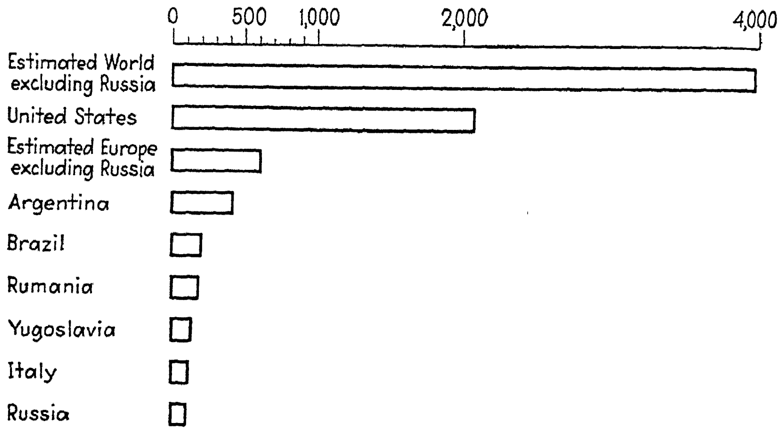


FIG. 9.—Corn production for the world and for selected countries, 1930–1931 (million bushels).

Corn is also known as maize, particularly among the inhabitants of Great Britain. There are a number of cultivated varieties of corn, all included under the botanical term *Zea mays* as classified by Linnaeus. These have been further divided into subspecies by Sturtevant as follows:

Zea mays indentata, dent corn.
Zea mays indurata, flint corn.
Zea mays everta, pop corn.
Zea mays saccharata, sweet corn.
Zea mays tunicata, pod corn.
Zea mays amylacea, soft corn.
Zea mays amylea-saccharata, starchy sweet corn.[1]

[1] For a key to these species groups see W. W. Robbins's, Botany of Crop Plants, P. Blakiston's Son & Co., 1931.

TABLE 5.—INTERNATIONAL TRADE IN CORN
(1,000 bu.)

Country	Year beginning July									
	Average 1925–1926 to 1929–1930		1930–1931		1931–1932		1932–1933		1933–1934*	
	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports
Principal exporting countries:										
Argentina	220,588	0	274,044	0	386,849	0	206,902	0	218,542	0
Rumania	30,906	21	38,301	1	54,363	3	67,919	....	....	....
United States	23,233	1,637	3,317	1,747	3,969	386	8,775	195	4,965	244
Union of South Africa	19,446	376	21,880	30	10,998	27	16,786	25	148	1,269
Yugoslavia	8,534	......	14,923	......	3,467	....	16,369	....	23,260	....
Principal importing countries:										
United Kingdom	2,512	71,650	2,595	83,280	3,183	114,684	302	109,589	366	112,849
Netherlands	788	44,523	863	48,785	518	69,910	223	58,945	33	43,505
Germany	23	42,826	2	17,320	0	29,723	1	17,744	0	10,493
France	69	27,349	126	36,788	124	46,513	16	40,422	42	26,756
Belgium	1,080	24,268	1,589	27,224	2,992	35,421	2,318	32,194	2,185	28,756
Italy	42	23,942	16	25,256	12	34,747	1,694	9,718	2,073	6,603

* Yearbook of Agriculture, 1935.

The world production of corn in recent years, as shown by Table 5 and Fig. 9, indicates that the United States produces about half of the world corn crop, and several times as much as any other corn-producing country.

The principal corn-exporting countries are Argentina, Rumania, United States, Union of South Africa, and Yugoslavia. Corn is not so important a crop from the standpoint of international trade as is wheat, largely because of its use for animal food close to the sources of supply. The leading importers of corn are United Kingdom, Netherlands, Germany, France, Belgium, and Italy.

In the United States the principal corn-producing states are Iowa, Illinois, Nebraska, Missouri, Indiana, Minnesota, Kansas, and Ohio, and the area embraced by these states is often called the American corn belt.

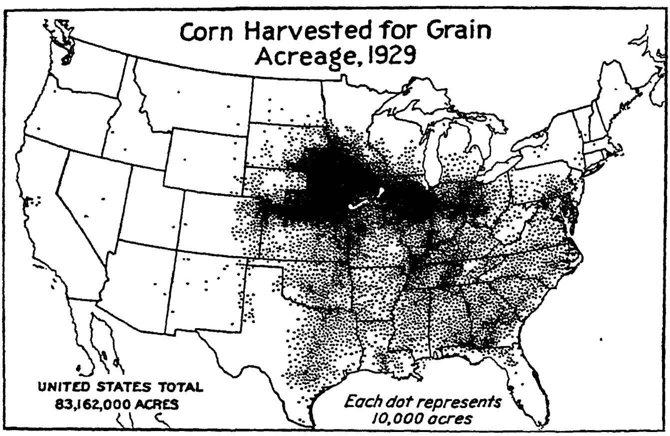


FIG. 10.—(*U. S. Department of Agriculture.*)

It is one of the most fertile agricultural regions in the world and supplies us with not only corn but a considerable portion of our beef and pork in addition. Table 6 indicates the relative production of corn in these states.

No product is more intimately connected with the progress of this country than corn, which constituted an important agricultural crop of the Indians and was immediately adopted by the earliest white settlers. The soil and climatic conditions required for corn are present in practically all of our Eastern, Southern and Central states.

Conditions necessary for the satisfactory growth of corn include heat and moisture. Most of the corn crop is produced where the mean summer temperature lies between 70 and 80°F., with night temperatures not much lower than 60°F. It grows rapidly and requires moisture particularly during the vegetative phases of its development, which in the

corn belt takes place during the month of July. The plant also requires a well-drained soil, although for maximum development the soil must also be rich. In most regions it requires about five months for corn to reach maturity. Corn is grown however, in many districts where its maturity may not be assured because of a shorter season, but the stalks under these conditions are used for ensilage whether the ears have entirely ripened or not. Ensilage has been found an efficient food for dairy cattle and is raised primarily for that purpose in numerous eastern states.

In those regions where corn is primarily grown for grain, the ears are commonly allowed to mature on the stalks. They fill out and eventually the kernels become hard, owing to the changes which convert sugars to starches in the mature kernel. The ears may be torn from the stalks by hand and thrown into wagons or trucks; or this part of the harvesting process is sometimes carried out by highly mechanized equipment. There are corn-picking and -husking machines which are said to enable one man to take care of all the corn from 8 to 10 acres a day. If the ears are removed from the stalk by hand, they may be husked in the field or transported to the barn and husked later. In the earlier days in this country it was customary to have the husking done by large groups of neighbors who attended the husking "bees" which were a prominent part of the winter social events in many corn-growing regions.

The corn kernel is composed of hull, endosperm, and embryo. The hull or exterior portion is made up of the pericarp which contains several layers, and the testa, the inner integument, consisting of two layers. The hull constitutes about 5 per cent of the whole kernel and is made up in part of fiber, wood gums, and pentosans, but contains only small quantities of starches, fats, and proteins.

The endosperm consists of the aleurone layer, a single layer of cells making up the outer layer of the endosperm; the starchy endosperm which includes the starch of the crown and the tip; and the horny endosperm. The endosperm constitutes over 80 per cent of the kernel and is principally starch.

The embryo, or germ, makes up approximately 10 per cent of the entire kernel and one-third of its contents are fat, the source of the now popular corn oil. An equal portion of the embryo is comprised of carbohydrate and about 20 per cent of protein. The high percentage of fat in the corn kernel makes corn richer in fat than either wheat, rye or barley.

The analyses, at top of page 46, taken from Leach give the proximate composition of corn from a chemical standpoint.

In addition to the other nutritional qualities of corn, it has been shown to contain small amounts of vitamin A.

	Water	Protein	Ether extract	Crude fiber	Carbohydrates other than crude fiber	Ash
Maximum	12.32	11.55	5.06	2.00	75.07	1.55
Minimum	9.58	8.58	2.94	1.00	68.97	1.19
Mean	10.93	9.88	4.17	1.71	71.95	1.36

Corn, like the other cereals, can be kept satisfactorily if its water content is low. It is subject to more rapid spoilage than most of the other cereals, particularly when ground whole, because of the high fat content in the embryo. It is subject to the same general insect infestations in storage as other grain.

TABLE 6.—CORN PRODUCTION IN THE UNITED STATES BY LEADING STATES*
(1,000 bu.)

State	Average 1927–1931	State	1933	State	1934
Iowa	413,751	Iowa	455,000	Iowa	201,480
Illinois	302,578	Nebraska	234,698	Illinois	146,760
Nebraska	230,00	Illinois	224,748	Indiana	94,141
Missouri	150,699	Minnesota	142,957	Ohio	92,200
Indiana	146,379	Missouri	141,446	Minnesota	76,619
Kansas	137,700	Indiana	127,263	Wisconsin	73,904
Minnesota	134,848	Ohio	112,694	Kentucky	62,832
Ohio	121,397	Kansas	80,431	Tennessee	58,894
South Dakota	95,748	Wisconsin	77,980	Pennsylvania	52,896
Texas	81,615	Texas	74,824	Alabama	47,950
Wisconsin	64,895	Kentucky	68,175	North Carolina	47,580
Kentucky	63,954	Tennessee	66,035	Texas	45,873
Tennessee	58,880	Pennsylvania	50,560		40,121
Oklahoma	53,843	North Carolina	44,252	Georgia	39,270
Pennsylvania	45,570	Michigan	42,315	Virginia	35,794

* Yearbook of Agriculture, 1935.

Corn Standards.[1]—"Corn shall be any grain which consists of 50 per cent or more of shelled corn of the dent or flint varieties, and may contain not more than 10 per cent of other grains for which standards have been established under the provisions of the U. S. Grain Standards Act."

There are three classes: Class I, yellow corn; Class II, white corn; Class III, mixed corn. There are five numerical grades and one sample

[1] Handbook of Official Grain Standards of the United States, U. S. G. S. A., Form No. 90, May, 1935.

grade. The No. 1 grade has a test weight of 54 lb. per bushel, the other grades being lower in test weight. The moisture content of No. 1 grade must not exceed 14 per cent, but this limit is increased progressively in the samples of lower numerical grade.

If corn contains more than 25 per cent of flint corn it is designated as flint corn in grading.

TABLE 7.—YIELD, VALUE, AND EXPORTS OF CORN PRODUCED IN THE UNITED STATES*

Year	Average yield per acre, bu.	Production in grain equivalents, 1,000 bu.	Price per bushel at Chicago, cts.	Net exports, per cent
1904	28.2	2,686,624	48	3.4
1909	26.1	2,611,157	59	1.5
1914	25.8	2,523,750	70	1.6
1919	27.3	2,678,541	159	0.2
1924	22.9	2,298,071	106	0.2
1929	25.9	2,535,546	83	0.4
1934	15.8	1,380,718	...	...

* Yearbook of Agriculture, 1935.

USES OF CORN

Corn has wide usage and consumption as a food in its "green corn" or milky state, which also serves as a basis for a large canning industry.[1] The grain is also the raw material for numerous other products such as corn meal, hominy, and cornstarch. It is also used in the manufacture of breakfast foods such as corn flakes and puffed corn. Corn meal has decreased tremendously in consumption in the past few decades, the per capita annual usage being 21.3 lb. in 1931 compared with 117 lb. per capita in 1899. Its largest usage today is in the South where the competition of other foods has not been so successful. The per capita consumption of breakfast foods made from corn has nearly doubled in the last decade. Corn is used in fermentations as the basic raw material for grain alcohol and distilled beverages, also butyl alcohol and acetone, and as a raw material for manufacture of sugar (glucose, sirups, and other products).

Most food animals and poultry are capable of using corn in its natural form or reduced somewhat in size by cracking.

Corn for human use is generally subjected to grinding or cooking operations, usually to both of these two types of treatment. Corn meal, maize meal, or Indian meal is meal resulting from the grinding of corn and should contain not over 14 per cent moisture, not less than 1.12 per cent nitrogen, and not more than 1.6 per cent ash. This product which

[1] "Green corn" will be discussed in the chapter on vegetables.

was one of the most commonly used foods for man in America may be obtained by grinding the whole kernel without removal of the germ or bran. The inclusion of the germ or embryo favors rapid deterioration, however, and lowers the keeping quality of the product, unless it is to be used within a relatively short time.

Hominy is made by treating the whole corn with dilute lye, boiling the kernels, washing off the excess lye, and subsequently cooking the mass until tender. The use of hominy has decreased somewhat with the development of many new cereal foods in recent years, especially in the North.

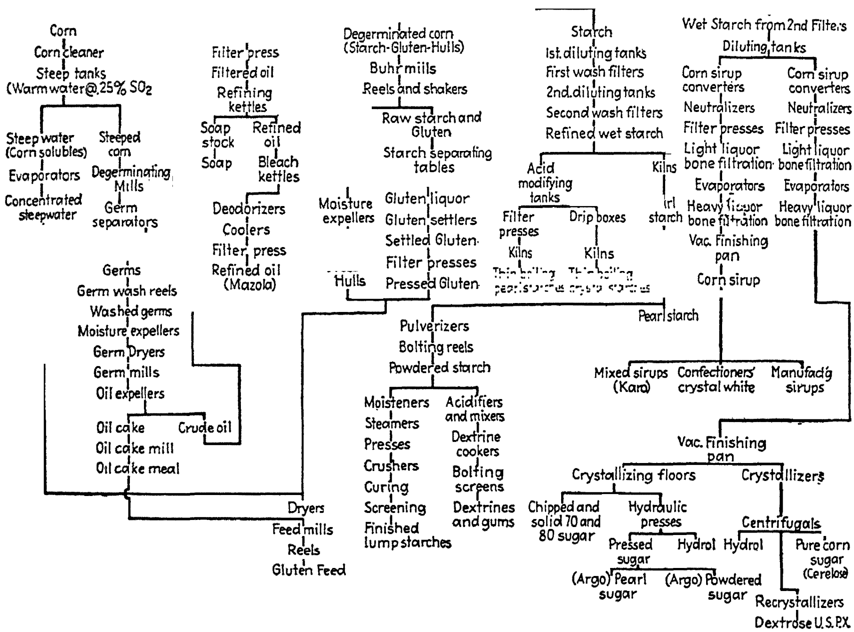


FIG. 11.—Flow sheet of corn products. (*Food Industries.*)

Popcorn is another special product that is familiar in most American homes and amusement centers. It is made by rapidly subjecting the kernels of *Zea mays everta* to heat in a thin metal or wire container. In the heating process, moisture in the kernels expands and the kernels are ruptured with explosive force. The popped corn with salt, butter, or molasses makes a popular food product.

Corn or its by-products have numerous other uses both as foods and for industrial purposes, and the manufacture of these various constituents and their refining has come to be an important American industry. While corn itself is exported to only a limited extent, its products are one of our valuable exports. In some recent years this industry has

utilized more than 3 per cent of the United States corn crop, or over 75 million bushels of corn as its raw material.

The accompanying diagram indicates the variety of products which may be made from corn kernels. Additional products are available from the remainder of the plant, the stalks, husks, and cobs.

The Manufacture of Corn Products.—The first general step in these processes by which corn products are made is the separation of the corn kernel into its constituent parts, the embryo or germ, the hull, and the endosperm. This is accomplished by soaking the corn in warm water containing a low concentration of sulphur dioxide in order to inhibit bacterial fermentation which would otherwise result. During the soaking period there are osmotic changes which cause some of the nitrogenous compounds of the corn and its mineral salts to go into solution in the so-called steep water. At the same time the grains become soft and the hulls are loosened.

The steep water when concentrated by heat is a rich source of protein and is used for cattle feed.

The soft kernels are next passed through crushing mills so regulated that the hulls, endosperms, and embryos are mechanically separated without further damage to the various components which are conveyed to long water tanks. A gravity separation takes place in the tanks as the germ or embryos are composed to a considerable extent of oils or fats and because of their lower specific gravity float on the surface of the water, while the hulls are heavier than water and sink to the bottom. The endosperms are intermediate in specific gravity and are suspended in the water but eventually tend to settle toward the bottom.

The corn embryos are removed from the top of the tanks by a water overflow or skimming process and are subsequently cleaned by washing. After drying and grinding, the embryos are subjected to pressure extraction to remove the corn oil, a product of value not only for food as a cooking oil, salad oil, or shortening, but also as a raw material for soaps, varnishes, paints, glycerine, and other products. That oil used for food products is generally subjected to further refining processes, during which a gum is separated which also has industrial uses in the manufacture of rubber substitutes. The press cake remaining after the oil is extracted from the embryos, corn-oil meal, is largely used for feed for animals. The consideration of corn oil as a food is discussed with other vegetable oils in a later chapter.

Starch is obtained from the material left in the tanks after the embryos are removed. The remaining endosperms and hulls are ground up finely by passing through grinding mills while in a semifluid condition and later bolted through very fine-mesh-silk bolting cloth which separates the larger fibrous portions, the hulls, from the starches and proteins

which are able to pass through the screen. The latter are again subjected to a gravity separation in long settling troughs in which the heavier starch settles to the bottom and the lighter protein constituent, gluten, is transported out of the tanks by water overflow. The gluten may be combined with corn-oil meal, concentrated steep water, and the hulls mentioned above, to make a valuable stock food.

The starch from the bottom of the settling tanks is later washed, cleaned, carefully dried in kilns, and is then available for food purposes, in the making of desserts, candies, baking powder and the like. It may also be used in the paper industry, the leather tanneries, laundries, or incorporated with other materials to serve such widely different purposes as a constituent of cosmetics, explosives, adhesives, and shoe polishes.

Cornstarch itself may be subjected to hydrolytic processes which convert the starch to dextrins, corn sirup, and corn sugar, which are all important products of commerce. The hydrolysis is accomplished by acidifying the starch with dilute hydrochloric acid and subjecting the material to steam under pressure. Under such conditions a number of products may be formed, dependent on the acidity, extent of heat treatment, and time during which the process is allowed to continue. In order of production, they are dextrins, maltose, and dextrose or corn sugar. Each is smaller in molecular size than those preceding and is the result of the breakdown of the larger molecule of the former and is accompanied by the chemical addition of water.

Maltose and dextrose are sugars—the former a disaccharide or 12-carbon sugar which, by this process of hydrolysis, may be converted into two molecules of dextrose, a 6-carbon sugar or monosaccharide. The dextrins are more complex carbohydrates, comprised of aggregates of the two above-named sugars, and starches are still larger and more complex combinations.

At different stages in the hydrolysis dextrins may be obtained; subsequently, corn sirup, which is a mixture of dextrins, maltose and dextrose; the final product is dextrose, or corn sugar.

Dextrins are used for adhesives in the paper industry, as sizing in the textile and cordage industries, and as glazing materials for food products such as rice.

Corn sirup is largely used in the confectionery industry in making candies. It is used to a certain extent in the preserving industry as a constituent of jams and jellies. Corn sirup may also be used either alone or together with other sirups which have more flavor, for table purposes.

According to Cathgart,[1] 43°Bé. corn sirup has the following approximate chemical composition:

[1] CATHGART, W. R., The Story of a Grain of Corn, *J. Chem. Ed.*, 4, 6–7, 1927.

	Per Cent
Water	17.5
Dextrose (calculated as reducing sugar)	34.7
Dextrin, nonreducing carbohydrates, not starch	47.5
Ash	0.3

Corn sugar is produced by a more prolonged hydrolysis similar to that of corn sirup, resulting in a more complete conversion of the more complex carbohydrates. The resulting solution is neutralized, decolorized with bone char, and evaporated in vacuum pans to the point of crystallization. It is then poured into special crystallizing forms and after partial solidification, cut into slabs. These slabs are the crude corn sugar, which may be subjected to pressure in order to remove a heavy sirup, known as "hydrol" which corresponds somewhat to the molasses of the cane-sugar refineries. Hydrol is generally not used for food purposes but as a raw material for fermentations. Its general composition is as follows:

	Per Cent
Water	20.0
Reducing sugar (calculated as dextrose)	56.9
Dextrin	21.1
Ash	2.0

If the sirup from the vacuum pans is permitted to crystallize, dextrose crystals are formed which may be separated from the hydrol by the use of centrifugal separators. These crystals are then dried and the resulting sugar is known as "cerelose." Its composition from a chemical standpoint is outlined below:

	Per Cent
Water	7.5
Dextrose	92.0
Dextrin, ash	0.5

Refined corn sugar is pure dextrose with some water of crystallization. Anhydrous corn sugar is dextrose with no water or other impurities. The crude sugar or cerelose may be used in certain candy coatings, in the tanning industry, in the artificial silk industry, in the manufacture of fermentation products such as beer, alcohol, vinegar, or lactic acid.

Refined corn sugar is used by bakeries in their various products, in the canning industry for sirups, and in other food industries. It is slightly less sweet than sucrose, the sugar obtained from cane and beets, which is in certain instances an advantage. In combination with sucrose in jams and jellies it tends to inhibit crystallization which is undesirable in such products.

The following definitions for sugars and sirups from corn were established in 1933 and are the government standards.[1]

Dextrose is the product chiefly made by the hydrolysis of starch or a starch-containing substance, followed by processes of refining and crystallization. (When derived from cornstarch, dextrose is known commercially as refined corn sugar.)

Anhydrous dextrose contains not less than 99.5 per cent dextrose and not more than 0.5 per cent of moisture.

Hydrated dextrose contains not less than 90 per cent of dextrose and not more than 10 per cent of moisture, including water of crystallization.

Glucose, mixing glucose, confectioner's glucose, is a thick, sirupy, colorless product made by incompletely hydrolyzing starch, or a starch-containing substance, and decolorizing and evaporating the product. It contains on a basis of 41°Bé. not more than 1 per cent of ash, consisting chiefly of chlorides and sulphates.

The estimated per capita consumption of certain corn products in the United States during 1931, according to the U. S. Department of Commerce was as follows: Cornstarch, 1.3 lb.; corn sugar, 6.43 lb.; corn sirup, 6.43 lb.; corn sirup mixed with other sirups, 5.79 lb.

Corn as a Raw Material for Fermentation Products.[2]—Carbohydrates from corn may be used as a raw material for bacterial fermentation processes under carefully controlled conditions with the production of butyl alcohol, acetone, and other solvents. This type of fermentation was carried on during the World War on a large scale because acetone was used in explosives and munitions. Since that time butanol has been found very useful, especially in the manufacture of lacquers for auto bodies and other metal surfaces.

This fermentation, brought about by bacteria which are members of the *Clostridium butyricum* (Prazmowski) group, is usually carried out on cooked, sterilized corn meal. The mash contains from 3 to 7 per cent corn meal in water and is kept at a temperature of about 37°C. The fermentation, which is anaerobic in character, is allowed to proceed from 36 to 48 hours. A complex series of reactions occur during which the principal acids, acetic and butyric acids, are formed. These are later transformed by enzymatic changes into intermediate products which are later converted into acetone and butyl alcohol. During the early stages of the fermentation, hydrogen and carbon dioxide gas are evolved which may be collected for use in the manufacture of other chemical compounds. The final fermentation products are butyl alcohol, acetone, and ethyl alcohol in the approximate ratio of 6:3:1.

[1] S. R. A. F. D. 2, Rev. 4, 1933.

[2] See Peterson, W. H., and E. B. Fred, *Ind. Eng. Chem.*, **24**, 237, 1932.

The stalks of the corn plant may be subjected to chemical and mechanical treatment which have as a result material suitable for paper stock, soundproofing products, pulp for the making of cardboard, rayon, and similar products. By fermentation it is possible to produce methane, an inflammable gas. By distillation of the stalks it has been possible to obtain xylose. Lignin is obtained by destructive distillation of the corn stalks.

The corncobs, when ground to a flour, may be used for the manufacture of plastic board and linoleum. Destructive distillation produces acetic acid, methanol, tar, and charcoal. Arabinose and xylose may be obtained by other distillation methods and the xylose may be fermented to form other products such as lactic acid, acetic acid, and alcohol. Another product obtained by digestion of the cobs is furfurol which is assuming importance in the chemical industry as a solvent.

The husks are found even today in some rural mattresses, but for many years they were commonly used for this purpose.

TABLE 8.—SALES OF CERTAIN CORN PRODUCTS IN THE UNITED STATES*

Calendar year	Cornstarch, 1,000 lb.	Corn sugar, 1,000 lb.	Corn sirup, mixed and unmixed, 1,000 lb.	Dextrins, 1,000 lb.	Corn oil		Feed	
					Crude, 1,000 lb.	Refined, 1,000 lb.	Gluten feed and meal, 1,000 short tons	Corn oil meal, 1,000 short tons
1927	906,476	896,739	1,064,821	103,340	39,524	67,511	648	38
1928	838,605	968,601	1,106,957	110,169	43,507	74,153	659	40
1929	879,560	894,986	1,111,153	114,486	53,661	78,913	634	27
1930	710,525	849,315	1,025,970	89,720	40,004	77,924	576	25
1931	635,974	802,052	929,342	79,136	41,076	71,537	479	21
1932	529,329	776,854	794,926	62,122	35,127	76,437	542	18
1933	741,854	836,650	1,000,941	86,222	37,246	81,153	508	23
1934	666,869	633,233	996,172	69,947	42,400	87,109	599	21

* Yearbook of Agriculture, 1935.

In 1931 there were 43 establishments primarily engaged in manufacturing corn products such as corn sirup, corn sugar, starch, and oil. These employed over 6,000 workers and produced products valued at almost 100 million dollars. The largest plants are in Illinois, Indiana, and Iowa, close to the large centers of corn production.

CHAPTER IV

MINOR CEREALS

RYE

Rye, *Secale cereale*, is a member of the grass family which is closely related botanically to wheat. Although it is capable of much greater harvests in this country, rye is much less popular here than in Germany, Russia, and Poland where rye bread has a more prominent part in the diet.

Table 9 indicates the relatively minor part that the United States takes in raising this crop and shows a decreasing trend in United States production in recent years.

TABLE 9.—INTERNATIONAL RYE PRODUCTION*
(1,000 bu.)

Country	Average 1921–1925	1931–1932	1932–1933	1933–1934	1934–1935
U. S. S. R.	706,347	865,699	866,880	952,308	....
Germany	255,937	262,977	329,255	343,570	299,496
Poland	206,884	224,500	240,556	278,460	222,764
Czechoslovakia	52,200	54,630	85,660	82,103	59,968
United States	63,965	32,290	40,639	21,150	16,040
France	40,645	29,518	33,876	35,337	32,642
Hungary	26,839	21,672	30,300	37,654	20,197
Spain	27,721	21,102	25,905	20,702	22,176
Lithuania	22,942	16,229	22,521	21,731	25,221
Sweden	21,911	11,146	17,094	18,128	20,865

* Yearbook of Agriculture, 1935.
The Canadian rye production in recent years has ranged from approximately 5 to 8 million bushels.

The most important rye-producing states in the past decade were North Dakota, Minnesota, Nebraska, South Dakota, and Wisconsin. These produced more than two-thirds of the crop. In 1933 and 1934, although the total United States production dropped about 50 per cent, the production of North Dakota has decreased to an even greater extent as is shown in Table 10 of rye production by states.

The greatest quantity of rye is produced in the plains of Northern Europe, which reach from the English Channel through Russia to the Ural Mountains.[1] Since this region contains Russia and Germany,

[1] SMITH, J. R., The World's Food Resources, 1919.

TABLE 10.—RYE PRODUCTION IN THE UNITED STATES*
(1,000 bu.)

State	Average 1922–1931	State	1933	State	1934
North Dakota.	13,759	Minnesota......	3,638	Minnesota.....	2,474
Minnesota....	6,269	North Dakota..	3,575	Wisconsin.....	1,768
Nebraska.....	3,234	Wisconsin......	2,260	Indiana.......	1,495
South Dakota.	3,193	Nebraska.......	1,712	Pennsylvania..	1,344
Wisconsin.....	2,329	Pennsylvania...	1,606	Michigan......	1,314
Michigan.....	2,027	Michigan.......	1,312	North Dakota.	1,030
Pennsylvania..	1,572	Indiana........	970	Ohio..........	819
Indiana.......	1,138	South Dakota...	760	Nebraska......	728
Illinois.......	778	Ohio...........	688	Illinois........	630
Montana.....	735	Illinois.........	625	Virginia.......	550
Iowa.........	688	Virginia........	578	North Carolina	495
Ohio.........	629	Iowa...........	429	Iowa..........	348
Virginia......	574	North Carolina.	420	New Jersey....	342
Colorado......	546	New Jersey.....	325	South Dakota..	328
New Jersey...	467	Montana.......	350	Maryland.....	300

* Yearbook of Agriculture, 1935.

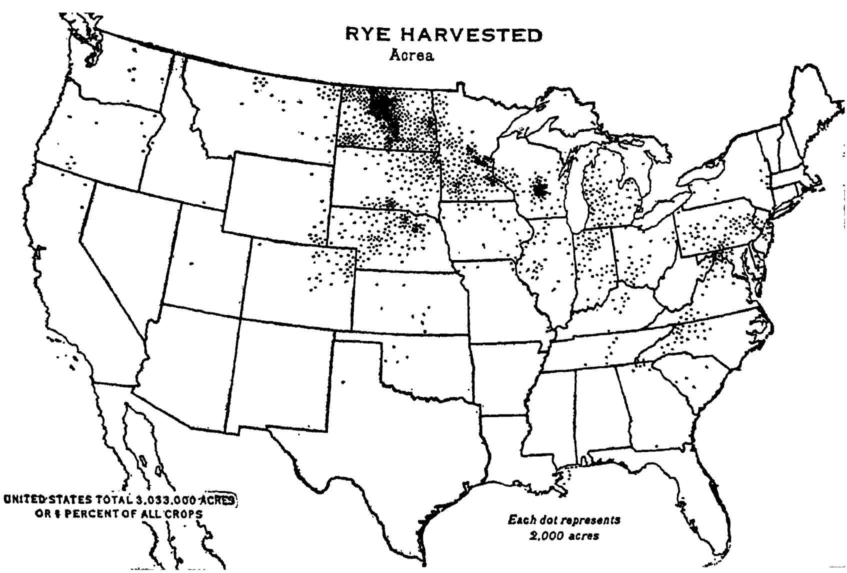


FIG. 12.—(*U. S. Department of Agriculture.*)

the two largest producers of rye in the world, about three-quarters of the world's rye originates here. In these countries dark bread is used much more than in America and is a very important part of the dietary of the inhabitants.

Rye is produced also in Canada, South America, Australia, New Zealand, Union of South Africa, but in lesser quantities.

The average yield of rye per acre for the United States was 12.8 bu. per acre for the year 1930. In New Jersey the average yield was 18 bu. per acre, while only 6.5 bu. per acre were harvested in Georgia and Montana for the same year.

Rye is a hardy plant and can be cultivated in any region where wheat will grow. Rye is also more resistant to fungous pests than is wheat. In addition it will grow in exposed areas, regions of cold, wet soils, dry soils, sandy soils, acid soils, and poor soils in general, because of the extensive branching of its roots and the depth to which they penetrate. It does not require so much nitrogen in the soil as wheat and will grow on soil which has not been well prepared. At temperatures only a little above freezing,[1] rye will germinate and grow. The advantages of a cereal plant having such a nature are of great value in many widely dispersed regions.

Rye does not contain so much gluten as wheat, but it is highly nutritious. It has been called the grain of poverty on account of the fact that it can be raised in regions where wheat is raised with difficulty.

In this country rye is raised chiefly as a grain crop for animal feed; in Europe principally for human consumption. (On some farms it may be grown as hay or for pasturage purposes.) Winter rye is often used as a green food for dairy cattle. Another important utilization of rye is as a raw material for the manufacture of distilled liquors, particularly rye whiskey.

The handling and storage of rye involve similar considerations to those of wheat. In 1927 about 1.7 million barrels of rye flour were milled in the United States and the estimated per capita consumption was approximately 2.8 lb. per capita.

U. S. Standards.—Rye shall be any grain, which, before the removal of dockage, consists of 50 per cent or more of rye and not more than 10 per cent of other grains for which standards have been established under the provisions of the U. S. Grain Standards Act. There are four numbered grades and a lower quality grade called sample grade. If rye has more than 14 per cent and less than 16 per cent moisture, it is defined as "tough" in addition to its grade designation. Other special grades are used for rye containing smut, garlic, or ergot above definite standards. The test weight of Grade No. 1 rye is 56 lb. per bushel.

[1] SMITH, J. R., The World's Food Resources, 1919.

BARLEY

Barley, *Hordeum*, is another member of the grass family which is important because of its grain or seed which serves as a food for man and animals in most parts of the world, and as the source of malt for brewing. Barley has been cultivated for centuries previous to the Christian era and was probably the most important grain of the Greeks and Romans.

The yield per acre of barley is very much higher than wheat. This would seem to make it an advantageous cereal grain, but unfortunately barley contains insufficient gluten to make bread which can successfully compete with wheat bread. In 1932 the average yield of wheat per acre was 13.0 bu. compared with 22.6 bu. for barley during the same period.

TABLE 11.—BARLEY PRODUCTION
(1,000 bu.)

Country	Average 1921–1922 to 1925–1926	1930–1931	1932–1933*
Russia	187,970	311,082†	231,024
United States	186,029	304,601	302,042
India	133,793	106,867	111,440
Germany	100,182	131,369	147,647
Spain	92,268	103,922	132,565
Japan	82,490	72,470	77,741
World (excluding Russia and China)	1,352,000	1,687,000	1,656,000

* Yearbook of Agriculture, 1932.
† Yearbook of Agriculture, 1934.

The countries in Table 11 are the world leaders in the production of barley. Under normal conditions the United States produces nearly as much barley as Russia, and nearly one-half of the world's supply of barley excluding Russia and China, for which no estimates are available, is furnished by the United States, India, Germany, Spain, and Japan.

Minnesota, California, Wisconsin, North Dakota, and Iowa lead the country in barley production. These states, with the exception of California, lie within the great grain belt of the North Central United States.

Barley is a grain which grows well in lands without a heavy rainfall. In southern California, it matures with less than 10 in. of rain.[1] Owing to its drought-resistant qualities, it may be planted in the arid lands bordering upon the Mediterranean Sea, in Asia Minor, and in Australia. On

[1] SMITH, J. R., The World's Food Resources, 1919.

the other hand, barley cannot withstand high precipitations, and is therefore not a good crop for zones of heavy rainfall. It has the ability to stand heat, and for this reason will be found growing in subtropical countries such as Egypt, Asia Minor, and North Africa.

Barley has a relatively short growing season, usually 60 to 70 days. This, with other characteristics and long days of sunshine, makes it possible to cultivate it up to the Arctic and even in the Arctic parts of Norway and Finland.

In Japan barley ranks next to rice in importance, being cultivated on the uplands which are not available for the growth of rice. On the mountains of Tibet and India it is cultivated up to the 14,000-ft. eleva-

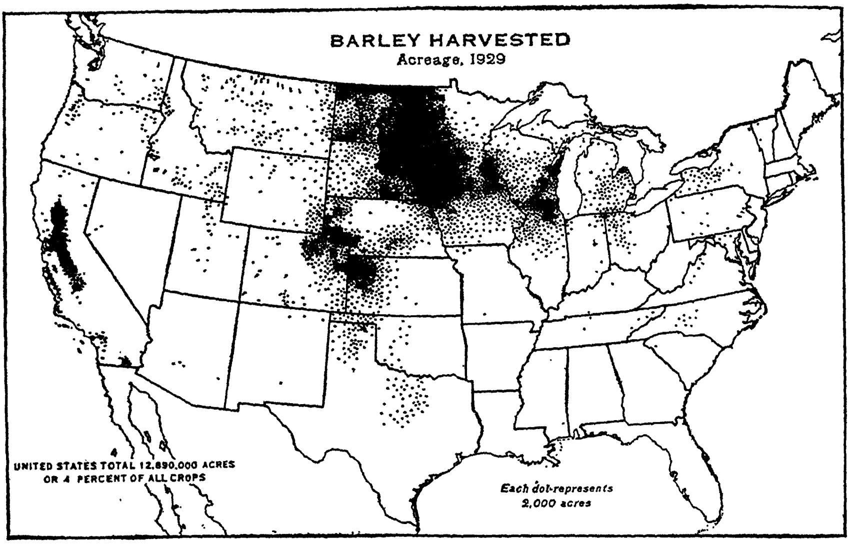


FIG. 13.—(*U. S. Department of Agriculture.*)

tion. Barley is used for food purposes, especially in Europe, Japan, and various other parts of Asia.

Barley is subject to a number of fungus diseases which are officially characterized as "blight." Helminthosporium blight is the term given to a disease which affects leaves, heads, seedlings, and kernels of barley caused by *Helminthosporium sativum.* Barley scab is a blight which affects seedlings, heads, and kernels and produces emetic substances which are poisonous to hogs feeding on such infected grain. This disease may be caused by *Gibberella saubinetii* and some other species of Fusarium.

The glumes and kernels of barley may be discolored by other fungi including Alternaria, Cladosporium, and Penicillium, according to Haskell of the U. S. Department of Agriculture.

According to the Official Grain Standards of the United States, barley is divided into four classes, Class I, barley; Class II, black barley; Class III, Western barley; and Class IV, mixed barley.

Malting barley is designated as Subclass *A* in Class I and consists primarily of six-rowed barley with white glumes grown east of the Rocky Mountains; it should contain at least 75 per cent of mellow barley kernels.

TABLE 12.—BARLEY PRODUCTION IN UNITED STATES BY LEADING STATES*
(1,000 bu.)

State	Average 1927–1931	State	1933	State	1934
Minnesota....	48,121	Minnesota.....	28,675	Minnesota.....	24,115
North Dakota.	39,577	California.....	24,471	California.....	22,682
South Dakota.	32,485	Wisconsin.....	17,710	Wisconsin.....	19,266
California.....	25,320	North Dakota.	17,580	North Dakota.	7,119
Wisconsin.....	21,288	Iowa..........	9,376	Iowa..........	5,712
Iowa.........	17,933	Nebraska......	8,390	Idaho.........	4,288
Nebraska.....	13,439	Colorado......	6,880	New York.....	3,969
Illinois.......	11,627	Illinois........	4,785	Michigan......	3,384
Colorado......	9,966	Idaho.........	4,147	Colorado......	3,024
Kansas.......	9,628	South Dakota.	3,451	Nebraska......	2,700
Michigan.....	6,130	Oregon........	3,334	Oregon........	2,597
New York....	4,975	Kansas........	3,264	Texas.........	2,457
Montana.....	4,585	Michigan......	3,250	Montana......	2,214
Idaho........	4,319	New York.....	3,200	Kansas........	1,988
Ohio.........	3,963	Washington...	2,590	South Dakota.	1,778

* Yearbook of Agriculture, 1935.

There has been an increased production of barley since 1918, despite the prohibition period which lessened the amount of barley used as malt for brewing purposes. This increase has been attributed to the high feeding value of barley, its possibilities of high yield, and the decline in uses for oats. In the North Central states it is grown particularly as a feed for livestock rather than as a cash crop, although the surplus may eventually be used for malting industries. It is the third most important crop in Wisconsin and the fourth in importance in Minnesota and the Dakotas.[1]

Minneapolis is the leading barley market of the United States and has annual receipts about twice those of Chicago. From this city it is shipped to malting concerns in neighboring states, to dairy or hog-feeding areas with feed deficits, and to Duluth for export via the Great Lakes.

California is a large exporter of barley, shipping an average of over 180,000 tons to Europe annually from 1930 to 1932. About 75 per cent

[1] SCHULTZ, Tariffs on Barley, Oats and Corn, Tariff Research Committee, Madison, Wisconsin, 1933.

of her exports went to the United Kingdom and 10 per cent to Belgium where it is very highly regarded for brewing purposes, because of its low protein content. This type of barley is not sought by Eastern maltsters in this country because of different brewing operations which favor a higher protein content in malt made from this grain.

The cultivated varieties of barley are included in four species (1) *Hordeum vulgare,* (2) *Hordeum intermedium,* (3) *Hordeum distichon,* (4) *Hordeum deficiens.* *Hordeum vulgare* is the six-rowed barley. Types of this species are used largely for feeds and malting purposes. *Hordeum*

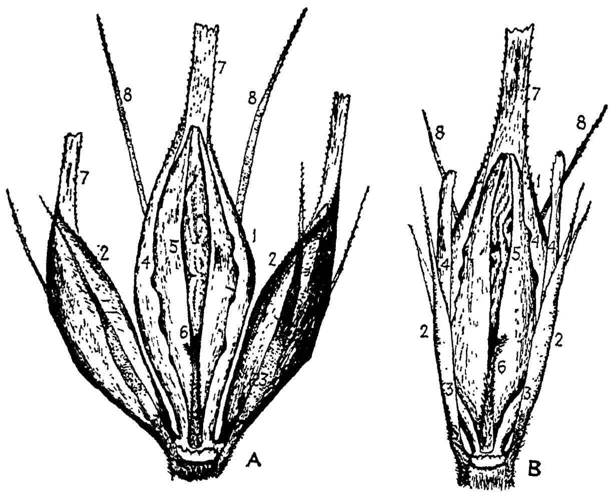


FIG. 14.—Spikelets from a single node of commonly grown barley.
A, Six-rowed barley (*H. vulgare*) showing median and lateral spikelets.
B, Two-rowed barley (*H. distichon*) showing median spikelet, and sterile lateral spikelets.
1, Median spikelet; 2, lateral spikelet (sterile in two-rowed barley); 3, outer glume; 4, lemma; 5, palea; 6, rachilla; 7, main awn (broken off); 8, awn on outer glume. (*T. A. Stoa, Varietal Trials with Barley, North Dakota Bulletin* 184, 1924.)

distichon is two-rowed barley, having softer plumper kernels which are suitable for some types of malt.

The varieties of barley commonly grown include Manchuria, Oderbrucker, Odessa, and O.A.C. 21. The first is grown mostly in western Minnesota and North Dakota; Oderbrucker is most popular in Wisconsin and Illinois; Odessa is grown mostly in South Dakota, and O.A.C. is the more prominent Canadian variety.[1] Of the two-rowed barleys, the Spartan variety is grown in Michigan and Alpha in New York, while in the Northwestern great-plains area Chevalier and Hannchen are raised. A relatively recent variety, Trebi, has gained considerable usage in Idaho and the Dakotas. In the Pacific coast states, the most prominent varie-

[1] HARLAN, H. V., *U. S. Dept. Agr. Farmers' Bull.* 1732, 1934.

ties grown are Coast, Coast and Atlas, and Club Mariout. The hardiest winter barleys are Tennessee Winter and Wisconsin Winter which are grown principally in the Southeastern states.

Barley has numerous uses.[1] It may be used as feed for poultry, hogs, horses, and cattle. Pearled barley may be used in soups and dressings.

Malted barley may be used in brewing, in distilling, in the production of baker's yeast. Malted-milk beverages require malted barley. It also finds utilization in the form of coffee substitutes, caramel, malt sirup which is used in bakeries, confectionery establishments, and as a pharmaceutical preparation. Breakfast cereals sometimes have malted barley as a component. The textile industries use malt sirup as a diastatic agent. Malt sprouts are used as a source of nitrogen for yeast nutriment and also as a constituent of dairy feeds. Barley flour and barley meal are used as invalid and baby foods.

Pearled barley is the name given round pellets of the grain which are left after the outer portions, the hull and bran, have been removed by mechanical abrasion. The Chevalier variety is considered most favorable for this purpose because of its relatively large kernel size and more spherical shape. When barley is pearled, the yield should amount to somewhat over 50 per cent of the original weight, provided the grain is unbroken and not weather-damaged.

Barley flour is a comparatively new product. War needs showed that it could be milled in much the same way as wheat and incorporated with wheat flour to the extent of 1 part in 5 and still make satisfactory bread, although it has not sufficient gluten to make good bread of itself. Its color is darker than an all-wheat-flour loaf, which causes prejudice among American consumers, but it must be remembered that higher barley yields could mean more loaves per acre in a wheat shortage.

The term patent barley flour is used to indicate flour milled from pearled barley. According to Harlan, the first barley flour was too highly extracted, *i.e.*, some 70 per cent of the grain was converted into flour when it would have been more widely accepted had 60 per cent or less been extracted because of lower color and improved appearance.

Malt.—Barley malt is used in several different types of industries, as stated above, for breakfast foods and special food preparations; for malt sirups which may find use in the baking industry, for flavoring foods, or for medicines; in the breweries; as a diastatic agent or as a desizing agent in textile mills. There are usually three grades: standard, choice, and fancy.

In the brewing industry as practiced in America the primary requirements for malting barley are soundness and texture, color, freedom from weeds and other materials, and proper variety. The grains should be

[1] HARLAN, H. V., *U. S. Dept. Agr. Farmers' Bull.* 1464, 1932.

plump and mellow, sufficiently soft and starchy in appearance when broken, uniform in color, large in size, and have a fine wrinkling on the front side, according to Elders. Damaged, broken, or dirty grains are highly undesirable, as is barley which is hard, shrunken, of mixed variety, or that which has been prematurely harvested.

The preference of English brewers for a low-protein malt is due to the fact that they make their infusions at higher temperatures than the Americans and use temperatures such that the proteolytic enzymes of the malt are unable to function sufficiently to hydrolyze the albumins, which make the resulting product difficult to clarify. In Germany the intensive extraction methods commonly used are better suited for barley malts of lower protein content. These factors favor California malt barley as an export crop. In England the two-rowed barley is commonly grown, but it is admitted by many English brewers that better results are obtained when their home-grown malt is blended with the six-rowed varieties grown on our West coast, although neither may be entirely substituted for the other, according to Whitlock. The technical requirements of the English brewers are said by Grant[1] to require from 25 to 40 per cent of high quality, sun-ripened, six-rowed barley, which is not grown in England.

Barley malt is produced by germinating carefully cleaned and screened barley which has been graded according to size. The grain is then steeped in cool water for 30 to 72 hours, during which time the kernel absorbs water and swells. After steeping, the swollen grain is conveyed to chambers or large, slowly revolving drums where it is kept at a constant temperature maintained at an optimum for the germination process which also requires high humidity for about four days. The introduction of air currents is necessary because if the carbon dioxide content gets much above 3 per cent in the air or the temperature is too high, the germination is retarded. During this period the radicle thrusts itself out of the lower end of the grain and the acrospire or plumule is forced along the grain under the husk. Meantime, as the acrospire develops, enzymes are elaborated owing to the vital processes and the diastatic enzymes convert the starch present in the kernel into sugars, maltose and dextrose. By the time the acrospire has grown the full length of the grain, the starch has been hydrolyzed into sugars and when the desired stage has been reached, the sprouted grain is transferred to a kiln. Here the grain is dried but care is taken to keep the temperature sufficiently low so that the enzymes present are not inactivated. When the moisture content is reduced to approximately 5 per cent, which requires about two days, the malt is mechanically screened to remove the sprouts and is ready for market.

[1] GRANT, Empire Marketing Board, *Pub.* No. 62, Great Britain, 1933.

Table 13, compiled by the U. S. Department of Commerce, indicates the barley malt production in this country in several recent years. Wisconsin, Illinois, and New York were the leading producers of barley malt during this period. Estimates by the U. S. Maltsters Association indicate that in 1935 about 75 per cent of all domestic malt was used in breweries and approximately 15 per cent in distilleries. Since the repeal of prohibition, malt is also imported in large quantities (over 193 million pounds in 1934).

TABLE 13.—UNITED STATES PRODUCTION OF BARLEY MALT

	1925	1927	1929	1931	1933
Malt, bu..	22,097,619	21,591,	25,965,509	23,646,896	34,769,766
Barley, bu	20,088,744	19,628,998	23,605,008	21,497,178	31,608,878
Value....	$21,716,533	$18,511,968	$20,822,600	$17,457,626	$26,129,305

The wastes from malt houses which are discharged into relatively small streams are likely to cause gross pollution because of the high quantity of organic matter, chiefly in solution, which is incident to the malt-house operations. A recent study in Wisconsin has shown that the average sewage wastes in such a plant amount to 75 gal. per bushel of barley processed. The highest organic content of sewage came from the steep water. A satisfactory method for the treatment of such wastes by means of a screening- and trickling-filter system[1] has been devised recently.

NOTE: For a detailed source of information on barley and barley malt the reader is referred to a compilation on this subject by the Grain division, Bureau of Agricultural Economics, U. S. Dept. Agr., 1935.

OATS

Oats, *Avena sativa,* is a member of the grass family, Gramineae. Its popularity is due much more to the fact that it makes an excellent food for animals and particularly horses, although it enters the human diet in the form of oatmeal and rolled oats or breakfast foods. The consumption of oats as breakfast foods amounts to over 6 lb. per capita in the United States, more than twice that of wheat and corn for the same purpose. The United States has been the leading world producer of oats for several decades, except when surpassed by Russia which has been a close competitor for first place. Germany, Canada, France, Poland, England, and Wales have been other important producers. The production in Argentina has shown a greater increase in recent years than any other country, however.

[1] RUF, WARRICK, and NICHOLS, *Sewage Works Jour.*, 7, No. 3, 1935. Wis. State Board of Health.

Although the common oats belong to the species *Avena sativa*, there are in reality two other species which are considered by some to be varieties of the former, namely *A. orientalis* and *A. nuda*. In Europe there are four other recognized species, *A. strigosa* (rough oats), *A. brevis* (short oats), *A. byzantina* (Mediterranean oats), and *A. abyssinia* (Abyssinian oats). Another species of oats is *A. fatua* (wild oats), which grows taller than common oats but is not a desirable food crop. Common oats may

TABLE 14.—INTERNATIONAL OAT PRODUCTION
(Million bushels)

Crop year	World excluding Russia and China	Europe excluding Russia	United States	Russia	Germany	Canada	France	Poland	England and Wales	Argentina
1894–1895	2,339	1,453	750	683	453	...	294	...	119	..
1899–1900	2,646	1,464	937	995	474	...	308	...	99	2
1904–1905	2,713	1,430	1,012	1,124	478	...	291	...	112	4
1909–1910	3,385	1,865	1,014	1,163	629	376	383	...	104	36
1914–1915	3,213	1,683	1,066	915	623	333	318	...	93	49
1919–1920	2,988	1,320	1,107	.....	310	419	180	76	110	31
1924–1925	3,574	1,572	1,424	613	390	431	306	106	105	53
1929–1930	3,647	2,060	1,118	1,084	509	301	373	203	107	68
1934–1935	2,680	1,641	529	.....	376	345	286	157	78	78

* Yearbook of Agriculture, 1935.

be bearded or beardless and the grain varying in color from white to black, brown, or yellow.

According to the U. S. grain standard as of July 1935, oats are defined as follows: "Oats shall be any grain which consists of 80 per cent or more of cultivated oats. Oats may contain not more than 10 per cent of wild oats." Oats shall be divided into five classes as follows: Class I, white oats; Class II, red oats; Class III, gray oats; Class IV, black oats; Class V, mixed oats; yellow oats are included in Class I."

There are four numerical grades for oats, and a lower sample grade, which may be applied to any of the above classes. The test weight of Grade No. I oats is 32 lb. per bushel.

In addition to the above standards there are special grade definitions for other oats, such as feed oats, and mixed feed oats.[1]

Oats are raised to some extent in every state in the country. It may seem peculiar that they are cultivated in the corn belt, but the method of culture makes this possible. Oats may be sown before the corn is planted. They require no attention during the growing season and are ready for harvesting at the time when the cultivation of the corn has

[1] See Handbook of Official Grain Standards of the U. S. G. S. A., Form 90.

been completed and the corn is reaching maturity but is not yet ready for harvesting.

Oats can be grown in soil which is adapted to wheat growing, but limestone regions are not desirable. In general, a greater variety of soils is suitable for the production of oats than wheat.

Oats require relatively small quantities of water but withstand more precipitation than wheat. This is due in part to the fact that the blossom and also the grain hangs over in a manner similar to fruit. Thus it is possible for the blossom to be fertilized in weather which would be disastrous to the wheat plant. On the other hand, oats cannot endure

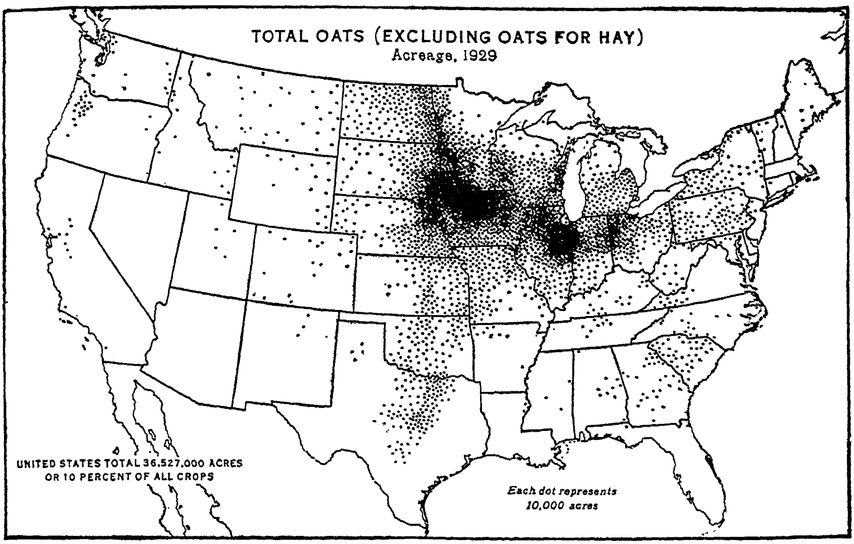


FIG. 15.—(*U. S. Department of Agriculture.*)

droughts as well as wheat. For this reason, oats are not widely grown in dry regions such as parts of California and Australia.

Owing to its shorter growing season, oats can be grown nearly up to the Arctic Circle, in such countries as Sweden, Finland, and Russia. The cool, damp climate of Scotland, Ireland, Norway, Denmark, Holland, and Belgium makes it possible to raise crops which are of much importance to these countries.[1]

The climate of the Northern wheat regions permits the growth of oats as well as that of the rye and barley regions. Oats can flourish under conditions of greater heat than is the case with wheat.

Oats for human consumption are used mostly as a breakfast cereal. The gluten content of oats makes the use of oats for bread out of the

[1] SMITH, J. R., The World's Food Resources, Henry Holt & Company, New York, 1919.

question. Oatmeal bread has a limited production but is usually made by mixing wheat flour and oatmeal. As a food for horses, oats are unsurpassed.

TABLE 15.—OAT PRODUCTION IN THE UNITED STATES BY LEADING STATES*
(1,000 bu.)

State	Average 1927–1931	State	1933	State	1934
Iowa...........	214,01	Iowa............	143,58	Minnesota...	72,703
Illinois..........	139,955	Minnesota.......	96,40	Wisconsin....	65,352
Minnesota.......	138,859	Illinois..........	78,76	Iowa.........	61,250
Wisconsin........	84,7	Wisconsin.......	63,88	Illinois.......	33,319
Nebraska........	67,01	Missouri........	32,634	Texas........	32,466
Ohio............	63,826	Indiana.........	28,730	Michigan.....	28,717
Indiana..........	61,3	Ohio.............	26,096	Ohio.........	25,994
South Dakota....	59,22	Kansas...........	25,976	Pennsylvania.	24,915
Michigan........	45,707	Michigan.........	23,541	New York....	23,408
North Dakota....	38,074	Nebraska.........	23,37	Oklahoma....	20,150
Texas...........	37,047	North Dakota....	22,139	Indiana......	18,225
Missouri.........	36,65	Oklahoma........	21,478		16,094
Kansas..........	32,929	Pennsylvania.....	20,812	Missouri......	13,585
Pennsylvania.....	29,069	Texas............	20,808	North Dakota.	8,886
New York........	26,861	New York........	16,810	Nebraska......	8,568

Yearbook of Agriculture, 1935.

RICE

Rice (*Oryza sativa*) is a cereal and, like many of the grains, a member of the grass family. Roots of the plants are not so well developed as those of oats, wheat, barley, and rye—a fact which is unquestionably associated with the large amount of water supplied and the nature of the soil to which the rice plant has become adapted. Each plant has from 5 to 25 stems and may grow to a height of 2 to 5 ft.

Rice is estimated to serve as the main source of food for about a third of the earth's population. It is very nutritious and easily digested. When conditions are favorable, as they are in parts of China and India, crops yielding as high as 115 bu. per acre have been harvested. The value of such a crop under highly intensive cultivation is great, but the regions where it may be grown are limited by its habits of growth.

Despite the fact that rice serves a most important part in the dietary of the Eastern peoples it is used to only a minor extent in the United States. The apparent consumption of cleaned rice per capita in this country is slightly over 5 lb. per year, although it was higher during the

World War when rice was used rather commonly as a substitute for potatoes which were scarce and high in price.

There are seven main varieties grown in the United States, four of which are called long-grain varieties, Rexoro, Fortuna, Edith, and Lady Wright. The short-grain varieties are Blue Rose, Early Prolific, and Japan. Blue Rose is the most common variety grown in the South and constitutes about two-thirds of the crop.

Rice production, in terms of cleaned rice, for the specified countries is as shown in Table 16.

TABLE 16.—INTERNATIONAL RICE PRODUCTION.*
(Million pounds)

	Average 1921–1922 to 1925–1926	1930–1931	1932–1933†
India	70,270	70,771	68,667
Japan	18,107	20,516	18,972
French Indo-China	7,704	7,990	8,117
Java and Madura	7,055	7,908	8,188
Siam	6,065	6,620	7,018
Chosen	4,556	6,026	5,066
Philippine Islands	2,744	2,928	....
Taiwan (Formosa)	1,747	2,315	2,804
United States	990	1,231	1,122
World (exclusive of China)	126,000	134,000	131,000

* Yearbook of Agriculture, 1932.
† Yearbook of Agriculture, 1934.

An examination of the statistics in Table 16 reveals the facts that India produces over one-half of the world's rice (exclusive of China) and Japan approximately one-seventh. Statistics are not available regarding China's production, but it is undoubtedly the greatest rice-producing country in the world.

TABLE 17.—RICE PRODUCTION IN THE UNITED STATES*
(1,000 bu.)

State	Average 1927–1931	1933	1934
Louisiana	18,537	15,957	15,957
Texas	8,913	7,685	7,738
Arkansas	8,379	7,056	6,936
California	7,823	6,360	7,665

* Yearbook of Agriculture, 1935.

Rice in this country is produced chiefly in four states, namely, Louisiana, Arkansas, Texas, and California. Louisiana produces about 40 per cent of the yield in the United States.

Although rice is produced in the above states at present, the first rice grown in this country (1694) was in the colony of South Carolina. Rice was chiefly cultivated on the tidal land in South Carolina, North Carolina, and Georgia, with a small amount in Louisiana, until about the middle of the nineteenth century. With the advent of the Civil War, rice culture drifted to Louisiana, which became in 1889 the leading state. Irrigation for the rice was provided from nearby sluggish streams. Texas, and later Arkansas, became important rice producers with the advent of irrigation. This crop has been grown extensively in California in the last two decades and is an important crop in Hawaii.

During the years 1919 to 1928, California produced an average of 54 bu. of rice per acre, as compared with 46.6 for Arkansas, 38.9 for Texas, and 35.6 for Louisiana. The average yield for this country for the same period was 40.5 bu. per acre (including Missouri). In 1931 the average yield for the country had increased to 46.4 bu. per acre.

Rice is grown chiefly east of the Suez. Other regions of growth, besides those already mentioned, include Mexico; Central America—Guatemala, Salvador, Costa Rica, etc.; Brazil; Argentina; Belgian Congo; Madagascar; Fiji Islands; French West Africa; Egypt; Europe—Spain, Portugal, Italy, Yugoslavia, Bulgaria.

British India, Indo-China, Siam, Italy, United States, Spain, Egypt, and Madagascar are the principal exporting countries. China consumes her own crop and imports millions of pounds of rice annually.

Rice requires much warmth, abundance of moisture, and a long growing season. It grows best in the torrid zone, but is successful in the warmer parts of the temperate zones. The amount of moisture necessary is phenomenal. During the growing season, ½ in. of water is required each day. Although certain regions normally receive sufficient rainfall to insure the success of the rice crop—as, for example, certain parts of the Philippines which receive a rainfall of 40 to 60 in.—irrigation is necessary for a dependable crop. Rice is grown extensively in swamp lands. Altitude is no barrier to the cultivation of rice. In certain parts of the world, the mountain sides have been terraced and flooded for the growth of rice.

Generally the rice grown without irrigation is a special variety of rice known as upland or hill rice.

Rice requires a watertight subsoil. This subsoil is best when of clay material and located 1 or 2 ft. below the surface of the ground.

The rice seed is sown by means of a grain drill on comparatively dry ground. A certain amount of moisture is necessary for the germination

of the seed, but too much will cause rotting. Fields usually are flooded to the depth of an inch or two when the plants become 6 in. tall. As the season progresses, the amount of water is increased until it is about 6 in. deep. Water must be changed continuously to prevent stagnation. Like other cereal plants, the rice crop is damaged by weeds, diseases, and insects.

Irrigation may be provided by means of dipping with pails, by water wheels, by pumping, by gravity, or by overflow. The method employed depends upon the facilities, the customs, and the wealth of the people of the region. After the rice has matured, the fields are drained and the ground permitted to become firm. Harvesting is then carried out in a manner similar to that of wheat. Rough rice is the rice as threshed and is also known as paddy.

Rice Milling.—In the milling process, rough rice is passed between two horizontal stones, known as buhr stones, the top one revolving and the bottom one remaining stationary. The hull is split and the kernel drops out.

The rice, with hulls removed, is sifted in a stone reel of 14-mesh wire. Germs, broken hulls, and bran are removed, kernels, hulls, and unbroken rice are passed on to a monitor, a machine which removes the loose hulls by suction.

A shaking machine, known as a paddy machine (paddy referring to threshed rice which is held firmly in the hull), causes a separation of the heavier hulled grains from the lighter paddy grains. At the end of this operation, the kernels contain nearly all the bran but are free from the hulls. Such rice is known as brown rice. Unbroken rough rice is again passed through buhring stones and the stone reel.

Brown rice is next passed through a huller. The kernels pass between two cylinders: the outer one is horizontal and stationary; the inner one, which rotates, is grooved and tapered. Passage of the brown rice through this machine results in the removal of a portion of the bran coating. The material is next sent through huller reels to remove the bran by sifting.

The last portions of bran are removed by means of pearling cones, consisting of a cone of stone within a cone of heavy iron screening. Rice enters the machine from the top, and rotation of the stone cone produces a fairly gentle removal of the bran. Material from the pearling cones is passed into reels for separation of the kernels and bran.

Rice carried through the foregoing processes usually contains a little residual bran and the surfaces are rough. Such rice is termed "unpolished rice."

It is customary to permit the product from the hullers and pearling cones to cool before proceeding to the polishing by the brushing machines, since the kernels become warm in these processes.

In polishing, rice is allowed to run down between two vertical cylinders. The inner one is covered with leather strips and revolves rapidly, causing the rice to be rubbed and polished as it passes down between this cylinder and the fixed outer cylinder of iron screen. A current of air cools the rice and blows the dust from it. Rice after this treatment is known as polished rice.

Official Definitions.—Rice is the hulled, or hulled and polished, grain of *Oryza sativa* W.

Brown rice is the hulled, unpolished grain.

Polished rice, "rice," is the hulled grain from which the bran or pericarp has been removed by scouring and rubbing.

Rice flour may be made by milling the polished rice. This is used in China for the manufacture of paste and noodles which are very commonly used in the Orient.

In addition to the use of rice as a food in its original form, it is used in Asia as a raw material for the manufacture of fermented and distilled beverages, after hydrolysis of the starch by mold enzymes.

CHAPTER V

VEGETABLES

Vegetables constitute a considerable portion of the diet of the world's population. Under this head are included a great variety of plant products. Some are eaten raw as greens and salad materials, while others are boiled, baked, or cooked in conjunction with meats or other food materials.

Such widely varying food materials as are included among the vegetables provide opportunities for a well-chosen and adequate diet if proper care is taken in selection. The so-called vegetarian or person who limits his diet to plant foods is not rare in our own country, although this type of individual is more common in lands having a scarcity of animal foods or where racial and religious customs become a controlling factor.

The use of fresh vegetables in the United States has increased markedly in the last two decades. Along with this greater demand for vegetables has come an agricultural system which endeavors to supply fresh food materials at practically all seasons of the year. This has resulted in developing various areas in this country for special vegetable crops at different periods of the year in order to supply the demands. The irrigated Imperial Valley in southern California and parts of Florida and Texas are examples of such specialized land utilization. As some of these regions are far removed from the larger markets of the North and East, there has arisen the necessity for improved facilities for the shipment of these perishable foods over long distances, and for better methods of packing and increased care in harvesting and handling. Developments in refrigeration both before and during transportation have played an important part in facilitating such shipments.

The more extensive utilization of vegetables in the diet has also been partly responsible for the development and improvement of preservation processes. This is especially true of the canning industry to supply which vast areas of cultivated land are now used each year. An illustration indicating the large acreages used for vegetable growing is that of peas, which required 112,200 acres for fresh market products and 312,600 acres for peas grown for manufacturing purposes in 1935. The relatively new methods of quick freezing which have been extended to vegetables are also destined to require much larger areas for the cultivation of their raw materials in the years to come.

Climate and the Cultivation of Vegetables.—Many vegetable crops of a more hardy nature can be grown in practically every state, but certain climatic conditions and soil conditions are bound to favor specific plants. Rainfall, temperature, intensity of sunlight, relative humidity, length of growing season and other factors cannot be neglected in determining the best regions for the cultivation of special crops. Soil composition and fertility are also of significance, as are the plant diseases which may be prevalent in particular districts. As a result of many years of experience certain areas have been found more productive for certain crops because of one or more of the favorable factors cited, and these areas have in some instances become the major producing regions. The state of Maine is an admirable example of this nature. In 1934, the average yield of potatoes per acre was 325 bu., while the average for the entire country in that year was 116 bu. Potatoes are grown in every state but few have any large acreages which combine the climatic conditions and soil conditions to such splendid advantage.

There are, however, certain crops which require very warm temperatures and are therefore confined to limited areas possessing that type of climate. Such areas, of which the Imperial Valley in lower California is an example, may grow in the cooler months of the year those vegetable crops which can be cultivated only during the summer months in the more northern states.

Vegetable Handling.—The problems encountered in respect to vegetables are not confined to those of soil, climate, and growth. There are definite risks due to physiological and microbiological causes which enter into the harvesting, packing, and shipment of vegetables as well as in their storage. The selection of the crop destined for the market or cannery should start in the field. Plant diseases caused by bacteria or fungi may render vegetables unfit for consumption. Bruised and injured products are particularly susceptible to the entrance of the disease microorganisms. Hence infected, bruised, or obviously unsound vegetables should be segregated in the field and thereby prevented from infecting those products of higher quality. If sound vegetables are packed too closely in containers or subjected to crushing, deterioration is likely to ensue. Improper ventilation is another cause of potential spoilage. The vegetables are still alive after harvesting and the vital chemical processes, such as respiration of the individual vegetable, may go on for months thereafter. Many of these chemical processes involve the liberation of heat and moisture. These quantities of heat may not be of sufficient magnitude to be noticeable from small lots of a single plant product, but when bushels or carloads or tons are confined in relatively small spaces, there may be considerable increases in temperature, especially in the interior of the mass. Under these conditions of

restricted ventilation sufficient moisture may be produced, together with elevated temperature from the respiration of the vegetables, to set up conditions favoring the growth of spoilage organisms. These same conditions accelerate the action of enzymes which are inherent in the vegetable tissue and thereby hasten the breakdown of the products from the standpoint of keeping quality and value. The use of low storage temperatures is thus of extreme importance, but the optimum storage temperature for various vegetables may differ. In some cases storage at temperatures between 40 and 50°F. may be injurious, as is the case with sweet potatoes, although for many other vegetables these conditions would be quite satisfactory.

Vegetable Classifications.—Our important vegetables differ from each other in many respects. Some of these differences are of structure, origin, use, cultivation, and biological relationships. There are also numerous methods of classification for vegetables, according to Thompson.[1] Among the methods of classification sometimes used are:

I. Systematic botany.
II. Hardiness.
III. Part used for food.
IV. Methods of culture.

The following classifications are advocated by Thompson. The botanical classification shows the family relationship, but it must be understood that members of the same family do not necessarily have like qualifications or the same cultural requirements. Among the more important families and their representatives may be listed:

Chenopodiaceae, goose-foot family—beet, chard, spinach.
Convolvulaceae, morning-glory family—sweet potato.
Compositae, sunflower family—artichokes, chicory, dandelion, endive, lettuce.
Cucurbitaceae, gourd or melon family—cucumber, muskmelon, pumpkin, squash, watermelon.
Cruciferae, mustard family—brussels sprouts, cabbage, cauliflower, kale, mustard, radish, rutabaga, turnip.
Gramineae, grass family—sweet corn, popcorn.
Leguminosae, pulse or pea family—beans (kidney, lima, soy, etc.), peas, lentils.
Liliaceae, lily family—asparagus, garlic, leek, onion.
Polygonaceae, buckwheat family—rhubarb.
Solanaceae, nightshade family—eggplant, pepper, potato, tomato.
Umbelliferae, parsley family—carrot, celery, parsley, parsnip.

[1] THOMPSON, H. C., Vegetable Crops, McGraw-Hill Book Company, Inc., New York, 1923.

Sometimes it is customary to classify vegetables according to their ability to withstand temperature of varying degrees. Those vegetables are classed as hardy, which will withstand heavy frosts, and include kale, turnip, spinach, and onions and smooth peas. Beets, celery, lettuce, wrinkled peas, beans, and parsnips are some of the crops of the semihardy nature—those which will withstand light frosts and whose seeds will germinate at fairly low temperatures. Sweet corn, squash, tomatoes, and melons are ranked as tender vegetables, being those

TABLE 18.—THE PERCENTAGE COMPOSITION OF SOME VEGETABLES, AS PURCHASED*

	Refuse	Water	Protein	Fat	Total carbohydrate (including fiber)	Ash
Potatoes	20	62.6	1.8	0.1	14.7	0.8
Tomatoes		94.3	0.9	0.4	3.9	0.5
Corn (green)	61	29.4	1.2	0.4	7.7	0.3
Carrots	20	70.6	0.9	0.2	7.4	0.9
Onions	10	78.9	1.4	0.3	8.9	0.5
Cabbage	15	77.7	1.4	0.2	4.8	0.9
Asparagus		94.0	1.8	0.2	3.3	0.7
Peas (green)	45	40.8	3.6	0.2	9.8	0.6
Snap beans	7	83.0	2.1	0.3	6.9	0.7
Dried beans		12.6	22.5	1.8	59.6	3.5
Soybeans (dried)		9.9	36.5	17.5	30.8	5.3
AVERAGE COMPOSITION OF THE EDIBLE PORTION OF VEGETABLES						
Potatoes		78.3	2.2	0.1	18.4	1.0
Corn (green)		75.4	3.1	1.1	19.7	0.7
Carrots		88.2	1.1	0.4	9.3	1.0
Onions		87.6	1.6	0.3	9.9	0.6
Cabbage		91.5	1.6	0.3	5.6	1.0
Peas		74.6	7.0	0.5	16.9	1.0
Snap beans		89.2	2.3	0.3	7.4	0.8

* ATWATER and BRYANT, *U. S. Dept. Agr. Bull.* 28, 1906.

which will not withstand frost or whose seeds will not germinate at low temperatures.

The third method of classification groups the vegetables with reference to the parts used for food. Into one group go the vegetables whose underground portions—bulbs, tubers, roots, and corms—are eaten. Potatoes, rutabagas, beets, carrots, onions, and similar vegetables make up this group. Peas, beans, cucumbers, melons, eggplants, etc., make up a group composed of vegetables which are grown for their fruits. Cauliflower, broccoli, and similar vegetables form a group grown for their flower portions, while asparagus, rhubarb, cabbage, lettuce, and

the greens and similar vegetables constitute a group grown for their stems and leaves.

Another method is to classify the vegetables according to the methods of culturing them. From an agricultural viewpoint this is undoubtedly the best mode of classification, although this system does not recognize family relationships and combines various parts of the foregoing methods of classification. Thus beets, carrots, turnips, and radishes—root crops—while members of one group in this classification, belong to three distinct families. Asparagus, artichokes, and rhubarb are some of the vegetables forming the group of perennial crops (crops which planted one year will continue to produce for several years). The cucurbits, consisting of squashes, pumpkins, melons, and cucumbers make up another group. The greens, or pot herbs, cole crops (cabbage, etc.), peas and beans, and potatoes, respectively, constitute other groups.

Chemical Composition.—The chemical composition of the vegetables varies to a considerable extent, as is shown in Table 18.

In general, the green vegetables are largely composed of water, but the dried products such as dried beans and soybeans are concentrated sources of the three great chemical groups necessary for human nutrition, namely, carbohydrates, fats, and proteins.

Considerable difference may be noted in the percentages of these food components between the vegetables as they appear on the market and the edible portions, the most obvious case being corn. The change in this case is due to the large amount of inedible material which is represented by the husk and the cob.

In addition to the constituents noted above, the experimental work in nutrition constantly indicates the increasing importance of mineral salts, represented by the ash, and of the vitamins which are discussed elsewhere. Both of these foods, or food accessories, are to be found in many of the more common vegetables.

Certain of the vegetables are discussed below in more detail in order to illustrate the great variation in changes which may occur after such foods are grown, how they must be handled to prevent excessive damage, the utilization of some vegetables as a raw material for other food products, and other factors which relate to their utilization as food crops.

POTATOES (*Solanum tuberosum*)

Potatoes are the most valuable vegetable crop raised in the world. Germany ranks first in order of producers, partly because in addition to those grown for human food, enormous quantities of potatoes are grown for stock feed. Large quantities are used also for fermentations and the end product, industrial ethyl alcohol.

Most temperate countries raise some potatoes, but the more important producers are Germany, Russia, Poland, the United States, France, Czechoslovakia, and the United Kingdom, as is shown in Table 19.

TABLE 19.—WORLD POTATO PRODUCTION*
(1,000 bu.)

Country	Average 1909–1913	Average 1921–1925	1928	1932–1933
Germany........	,373,609	1,304,447	1,516,373	1,727,540
Russia..........	740,728	1,154,635	1,466,217	469,733
Poland..........	889,531	807,919	1,016,339	101,364
France..........	526,793	451,353	413,875	605,675
United States....	357,699	395,242	465,350	358,009
Czechoslovakia...	245,210	247,176	315,719	340,843
United Kingdom.	173,520	190,685	212,768	208,165

* Yearbook of Agriculture, 1930, 1934.

The United States exports and imports are comparatively small. Part of the imported potatoes are a selected and special pack from Prince Edward Island and Nova Scotia. The use of individual containers, both sacks and cartons, of convenient size and attractive appearance, affords the opportunity of advertising the potato crop of particular regions, as has been done from Prince Edward Island, and this practice seems likely to increase. In the United States this development has been particularly noted in products from the famous Aroostook County in Maine, also from the state of Idaho which has a reputation for its large potatoes which are well suited for baking.

Although early potatoes are grown in the Southern states for shipment to the large centers of population when high prices are prevalent, the late crop of the Northern states constitutes about 85 per cent of the entire

TABLE 20.—PRODUCTION OF POTATOES IN LEADING STATES
(1,000 bu.)

State	1915	1917	1920	Average 1923–1927	1928	1929	1932
Maine.......	22,010	20,250	22,140	36,994	39,820	50,120	40,460
Minnesota...	30,210	33,600	28,025	35,056	38,940	27,370	29,562
New York...	22,010	38,000	46,250	32,517	32,376	24,840	28,350
Pennsylvania	20,160	29,532	36,455	24,869	31,980	25,740	21,450
Michigan....	20,945	35,910	35,700	29,401	35,802	19,725	29,900
Wisconsin....	25,926	34,990	33,264	26,453	31,970	20,240	22,620

annual production. The preceding six states produce almost half of the potatoes in this country, although practically all the states produce some.

Maine may be regarded as the leading potato-raising state, although New York and Minnesota have occasionally surpassed it in production. Considerable variation is noted in all the states, which is partly dependent on weather conditions and partly due to economic conditions.

For some years past Maine has been the outstanding producer from the standpoint of yield also, the average yield being 325 bu. to the acre in 1934, which is 55 per cent higher than her nearest competitor in this respect, California. Many states have an average yield less than 100

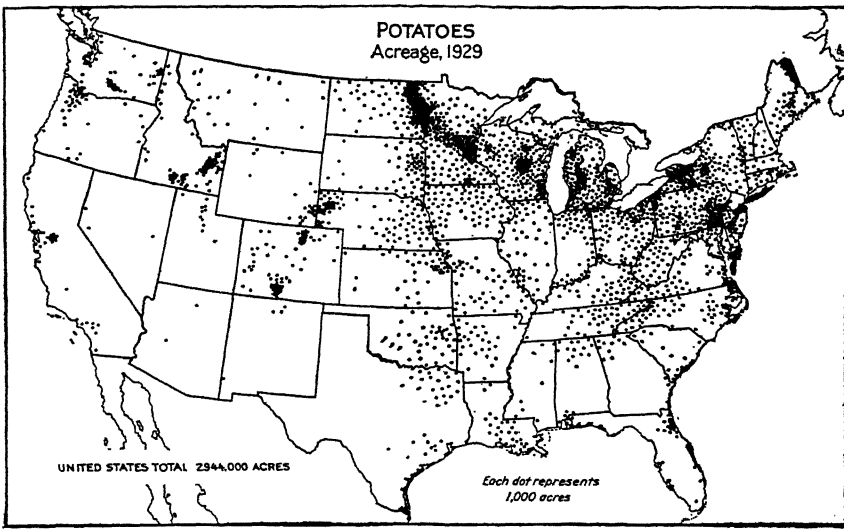


FIG. 16.—(*U. S. Department of Agriculture.*)

bu. to the acre, which shows the effect favorable climate and soil conditions may exert on particular crops.

There are numerous varieties of potatoes, but certain types have been found to be more successful in given areas and have become localized in that region. The Green Mountain varieties are particularly prevalent in New England, New York, and New Jersey, while the Rural group are more popular in Pennsylvania, western New York, Wisconsin, and parts of Iowa, Michigan, and Minnesota. For early planting in New England the Irish Cobbler, Triumph, and Early Rose are common.

The potato is subject to more diseases and insect infestations than almost any other cultivated plant. Lice, leaf hoppers, beetles, stalk borers, white grubs, and wireworms are prevalent in potato fields to a considerable extent. Of these insects, the Colorado beetle or common potato bug is the most destructive. The young beetles have soft bodies

and are hearty eaters of the potato-plant foliage. The insects on the aerial portion of the plant are controlled to a considerable extent by the use of Bordeaux mixture, Paris green, or other arsenic compounds. Lice and sucking insects may be destroyed with nicotine sulphate. Grubs and wireworms are restricted by late fall plowings, by which means the grubs are brought nearer to the surface and subjected to the cold of winter. Stalk borers are killed by splitting open the stems and crushing them. Potato plants and tubers are subject to a number of diseases which cause severe economic losses if not controlled. The tubers may develop both dry and wet rots owing to fungi. Bacteria sometimes cause slimy rots. One of the common fungous diseases known as "late blight," which affects both tops and tubers owing to the action of *Phytophthera infestans*, may be controlled by the use of Bordeaux spray. Blackleg tuber rot is a disease caused by bacterial infection of *Bacillus phytophthorus* and may be recognized by the black stem of the plants or the black decay of the tubers. The potato also is subject to bacterial wilt or brown rot caused by *Bacillus solanacearum* and other wilts due to fungi, such as Verticillium wilt which has *Verticillium alboatrum* as its causative agent. There are numerous scabs which cause surface incrustations on the tubers, the most common of these being caused by the attack of *Actinomyces scabies*. Certain of these and other potato diseases may be partially controlled by treatment of the seed with solutions of mercuric chloride or formaldehyde before planting. Other means of prevention of such maladies include the use of clean, selected seed not infected with such microorganisms or by careful soil rotation. Wilt and stem-end rot of potatoes may be caused by *Fusarium eumarti* and *Fusarium oxysporium*. The latter diseases may be partially controlled by selection of healthy seed, by long rotations of planting on infested soil or by planting on uninfected soil, according to Goss.[1] Storage rot may be lessened by holding the potatoes below 10°C. and with the humidity as low as possible without causing serious shrinkage. Two other potato diseases, spindle tuber and curly dwarf, are due to virus infections which may be spread by grasshoppers, flea beetles (*Melanoplus spp, Epitrix taeniata* and *Systeria*) the tarnished plant bug (*Lygus pratensis*) and the larvae of the Colorado potato beetle (*Leptinotarsa decemlineata*).

Potatoes are harvested on large farms by elevator diggers drawn by several horses or motivated by a gas engine.[2] Sometimes the nature of the soil, heavy clay particularly, requires that digging should be done by hand. The potatoes must be dry when placed in containers or in

[1] Goss, *Nebraska Agr. Exp. Sta. Res. Bull.* 27, 1924.
Goss and Werner, *Nebraska Agr. Exp. Sta. Res. Bull.* 44, 1929.
Goss, *Nebraska Agr. Exp. Sta. Res. Bull.* 53, 1931.

[2] Schrumpf, W. E., *Maine Agr. Exp. Sta. Bull.* 365, 1933.

storage. Splint baskets or slatted crates are used in picking up the potatoes. They are graded and sacked and are then ready for market. Nearly 50 per cent of the potato crop is in storage on the first of January, hence many potatoes are stored rather than marketed at once. As a rule, the growers in the early-crop districts, such as Florida, ship immediately, while in the Northern belt much of the crop is held in storage.

The life processes of the potato do not entirely cease in storage, although it is desirable to retard such processes as much as possible. Carbon dioxide is given off slowly as the potatoes respire, a condition favored by warmth. Excessive dryness causes a dehydration and shrinkage of the potato; moisture hastens the appearance of sprouts and combined with warmth provides conditions for rotting. Since potatoes

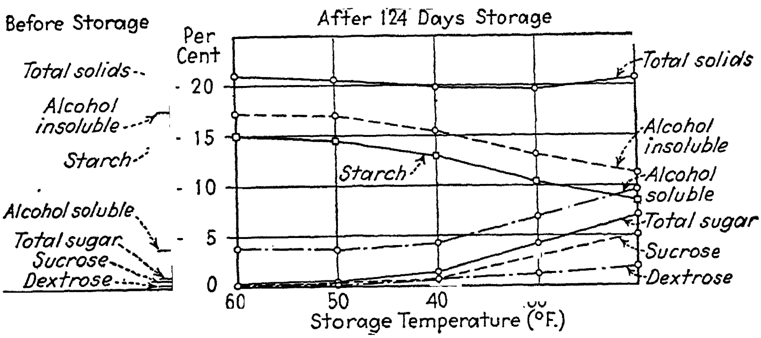


Fig. 17.—Effect of storage temperature on chemical composition of potatoes. (*Taken from U. S. Dept. Agr. Tech. Bull.* 507, 1936.)

are spoiled by freezing, they must not be allowed to remain at a temperature below 33°F. A temperature of 33 to 40°F. and a relative humidity of 85 to 90 per cent are satisfactory for the storage of potatoes. Too high a relative humidity causes a deposition of moisture on the potatoes, and too low a humidity causes drying. Potatoes should never be piled deep enough to prevent circulation of the air to supply oxygen and remove the carbon dioxide produced. Bins less than 5 to 6 ft. in height are preferable. Light is injurious to the table qualities of the potato and accelerates sprouting. It is necessary that stock going into storage should be dry and sound—free from rots and not mechanically injured.[1]

According to recent studies conducted by the U. S. Department of Agriculture, potatoes stored at lower temperatures, *i.e.*, below 50°F., tend to increase in sugar content and decrease in starch content.[2] This is of particular importance if the potatoes are to be used in the manufacture of potato chips or for French-fried potatoes. Those stored at

[1] Stuart, W., *U. S. Dept. Agr. Farmers' Bull.* 847 and 1064.

[2] Wright, R. C., W. M. Peacock, T. M. Whitman, and E. F. Whiteman, *U. S. Dept. Agr. Tech. Bull.* 507, 1936.

temperatures which favored increase in sugar content were seriously discolored during the cooking processes, owing to the caramelization of sugars.

The larger part of the fall potato crop is marketed relatively near to the point of production, but the very early potatoes for the Northern market are shipped some distance, as are those from Maine, Minnesota, and other large producing states later in the season. The type of car used for shipment depends upon the temperature. In the winter when there is great danger of freezing, cars with controlled-heating systems should be used, while in the spring and fall, boxcars are satisfactory. In the summer ventilated and refrigerated cars are best. In no case should the potatoes be piled too deep to prevent circulation of the air.

The following list of containers, including those in use in different areas, illustrate how customs vary in the handling of potatoes. A similar lack of uniformity may be noted in respect to many other food-shipping containers.

Bulk—Minnesota, Wisconsin, Michigan, New York, Maine.

Barrel (7,056 cu. in.), a little over 3 bu., single head with burlap top—Virginia, South Carolina, Maine.

Barrel, double head—Florida.

165-lb. burlap sack—New York, Maine.

150-lb. burlap sack—Minnesota, Wisconsin, Michigan.

120-lb., or 2-bu. burlap sack—Minnesota, California, Texas, Louisiana, Oklahoma, Kansas and most of the territory West of the Mississippi.

100-lb. burlap sack—territory West of the Mississippi.

100-lb. lug boxes—California.

½-barrel hamper—Florida, Texas.

50-lb. hamper—Florida, Texas.

⅝-bu. basket—early Northern grown.

To this list may be added the use of 15-lb. cotton or jute bags by the Aroostook County shippers of Maine, and the 25-lb. cotton bags used by the Idaho shippers. Bags of this nature are attractive, easy to handle and permit the free circulation of air. Paper-board cartons holding one peck (15 lb.) of fancy hand-picked potatoes are also seen in some of the better retail markets.

Frequently the potato production is such that there are available large quantities of surplus potatoes which can be used economically in the manufacture of potato flour or starch. Small, irregular or cull potatoes, if not used for stock food, may also be converted into these products.

Potato Flour.—Potato flour may be made in several ways.[1] In one process the potatoes are steamed without removing the skins, pressed through a device which removes the peel, and then fed between hot iron

[1] *The Potato Magazine*, January–February, 1919.

rolls from which the potato flakes emerge. The flakes are then milled, and flour of fine texture may be obtained. Another method is to clean the potatoes, peel them by machinery, cut them up into slices, and dry them in tunnel driers. The resultant material may be used as dried potato or may be ground up into flour. Still another procedure is to press most of the water from the potatoes and then dry them. Flour obtained by this last process is termed "pressed" potato flour.

Spray-dried Potatoes.[1]—Stones and pebbles are separated from the potatoes which are then thoroughly washed. The potatoes are cooked in steam with their skins on. After being cooked, the jackets are removed. Water is added, the mass mixed by a stirrer, and a thick, but freely flowing semiliquid results. The fluid is forced through spray atomizers from which it emerges as a fine mist. The mist is met by a hot blast of air, which instantly evaporates the moisture, permitting the potato solids to drop to the bottom of the spray chamber as a fine powder. The potato solids are bagged for market. It finds its principal use in the baking industry, but is also used for culinary purposes.

Potato Starch.—In the annual potato harvest there are considerable quantities of low-grade, unsalable potatoes, owing to irregular size, poor appearance, or other factors. These are nevertheless suitable for by-product uses including stock feed, the manufacture of starch and starch products such as dextrins and glucose, or fermentation products such as ethyl alcohol.

European potato-growing countries pay much more attention to the manufacture of potato by-products, especially starch and alcohol, than has been the case in this country, although our cull potatoes probably constitute more than 10 per cent of the total crop.

Potato starch is utilized in the textile industry in large quantities for sizing and finishing purposes, and for this use it is said to be preferable to starch from corn, rice, or other sources. Large quantities of potato starch are imported, especially from Germany and Holland, and our imports of this products have amounted to more than the volumes of our total domestic production in recent years.

The manufacturing processes are not particularly involved but for economical operation require large and constant sources of raw material over a period of several months, which is possible only in areas of large potato production. The manufacture of potato starch in the United States is carried on particularly in Maine in the prolific potato areas of Aroostook County, where over 15 million pounds were produced in 1931. In addition to cull potatoes, surplus potatoes of higher quality are sometimes available in periods of overproduction, particularly in the late-spring months as the storage period for potatoes is not unlimited.

[1] *Food Ind.*, **3**, 380–383, 1931.

Potatoes which must be kept for months before utilization should be stored at low temperatures, preferably between 45 and 50°F., but protected from freezing. Low temperatures retard spoilage by microorganisms and keep respiratory changes at a minimum. Metabolic changes due to enzymes, which may convert starch to sugar, proceed slowly even at low temperatures, however. Frozen potatoes may be used for starch manufacture but must be used immediately after they have been thawed, as otherwise they decompose very rapidly.

The first operation in starch making is to wash thoroughly the potatoes and remove as much as possible of the adhering soil and other foreign material. This is done in tanks, usually constructed of wood, where the potatoes are subjected to the action of a rotary forewasher which revolves them in a water bath, thus mechanically removing much adhering soil by attrition. After this they are propelled slowly through the remainder of the tank by means of paddles against a countercurrent stream of fresh water, which completes the process.

The cleaned potatoes are next ground or subjected to a rasping process, which reduces the potato to small fragments and frees the starch. The grinder used commonly in this country is a heavy wooden revolving cylinder faced with sheet metal which has its surface studded with projecting points surrounding punch holes. These jagged projections, formed as a result of forcing a metal punch through the metal before attaching to the cylinder, make an effective grinding or tearing surface. This type of rasp is replaced in European starch factories by a series of fine saw blades which comprise the surface of a revolving drum. The potatoes, together with a small stream of water, are fed into a hopper above the grinder and the revolving rasp is set so that the size of the potato fragment which may pass between the exterior of the grinder and the roll can be controlled. The grinder usually makes several hundred revolutions per minute and may have a capacity of several tons an hour. From a given weight of cull potatoes the starch obtained is approximately 12 to 15 per cent, so 7 or 8 tons must be ground for each ton of starch made. In Europe the potato fragments may be subjected to a second grinding but this is not practiced in the United States. In Germany this is sometimes accomplished by the use of specially designed millstones.

The finely divided effluent from the grinder with the water is conveyed to sieves having fine metal or silk screening of approximately 70 to 100 meshes to the inch. The sieve slopes slightly and is mechanically activated to assist in separating the particles which may pass through the meshes. The separation is also facilitated by fine streams of water sprayed on the sieve from above. The material which does not pass through the screen tails off the lower end of the sieve; it may be discharged with the plant wastes, or is made into cattle feed in this country.

In Europe these tailings or remnants of pulp are subjected to additional processing to increase the starch yields.

The milky filtrate containing the starch and potato juice is next run into large wooden vats where a gravity separation takes place for 12 or more hours, during which time most of the starch settles to the bottom. If the vat is 6 ft. deep, a layer of starch approximately 24 in. in depth will settle out, after the upper water is drawn off. The top of the starch layer called brown starch is more highly colored and less pure. This is removed by flushing with a water hose and draining off the water in which it is suspended. Then the remaining starch with additional water is stirred up by means of agitators, more water is added till the vat is full, and a second settling takes place. On completion of precipitation, the brown starch is again removed by flushing and the washed starch may be removed or washed again. It is essential that the temperature of the water and starch be kept as low as possible as otherwise the enzymes of the potato juice and the bacteria present are capable of causing appreciable losses in yield. In the warmer months ice is sometimes added to the vats, but the starch-making season usually ends in late spring before hot weather becomes troublesome. The brown starch is run into other vats and subjected to further purifications by gravity in order to recover more starch of lighter color, the suspended residue being then discharged with the plant wastes. Centrifugal machines may be used instead of gravity separation and are commonly used in Europe.

As starch making requires approximately a gallon of water per pound of potatoes a large supply of water of high quality is essential. In this country the starch factories are usually located on rivers which furnish the water and which often receive the plant wastes from the process. If these are voluminous, the latter may sometimes create nuisances as bacterial action takes place.

The next step in the process is to remove the white starch from the vats. This is done manually by shoveling out the sedimented starch which is hoisted to overhead platforms, and then conveyed to the drier. The drying apparatus is usually a kiln which is heated by means of furnaces or steam coils. The damp starch is spread out on slats placed about an inch apart at the top of the kiln, and as it dries and breaks, the lumps are dropped down in turn to a number of lower shelves. Each set of shelves is spaced closer together to enable better retention of the starch as it dries. When dried sufficiently, it is finally put into bags on the lowest floor.

Foreign practice in the better factories uses either belt, drum, or vacuum driers. These generally produce starch of better and more uniform quality than kilns, as it is difficult to control the temperature in kilns accurately.

Furthermore, the time required for drying in kilns is longer, and the starch is also likely to be discolored by dust and dirt which is carried into the kilns. As potato starch made by more careful technical methods is imported from Europe with a relatively high duty and commands a higher price than domestic potato starch, it would seem worth while to adopt improved methods in this country.[1] At present the potato-starch industry has not shown the progress of the corn-refining industry in scientific development.

Table 21 shows starch analyses by Balch and Paine of the Bureau of Chemistry and Soils, U. S. Department of Agriculture, who have investigated the possibilities of starch production from sweet potatoes.

TABLE 21.—ANALYSIS OF WHITE-POTATO STARCH*

Source of sample	Ash per cent			Water-soluble material, per cent	Protein ($N \times$ 6.25), per cent	HCl-insoluble material (Rask method), per cent	White-potato starch, per cent		
	Total	Water-soluble	HCl-insoluble				Moisture	Original	Moisture-free basis
Prime (Minnesota)	0.309	0.026	0.056	0.385	0.100	0.193	11.87	86.36	97.99
Superior (Maine)	0.365	0.143	0.133	0.205	0.175	0.200	14.64	84.12	98.55
Pearl (Maine)	0.247	0.204	0.022	0.265	0.138	0.159	16.83	90.10	96.31
Imported (Holland)	0.258	0.109	0.025	0.080	0.100	0.083	17.33	81.44	98.51

* BALCH and PAINE, *Ind. Eng. Chem.*, 23, 1205, 1931.

SWEET POTATOES (*Ipomoea batatas*)

Although persons living in Northern United States and Canada are generally familiar with the use of sweet potatoes—since this vegetable is by no means rare in the markets of these areas—the importance of this plant to the people in the South is hardly appreciated. In the states in which it grows the sweet potato serves as the principal vegetable food of millions of people, as the white potato does in the Northern states. It is extensively grown from New Jersey along the Atlantic coast to Florida and along the Gulf coast to Texas. The entire coastal plain of this great area has a climate well adapted to this member of the Convolvulaceae or morning-glory family. Moreover, it can grow well in sand and poor soil. If properly fertilized, very high yields may be obtained, but even under unfavorable conditions, *i.e.*, light soil and drought, the sweet potato does

[1] WALTON, R. P., A Comprehensive Survey of Starch Chemistry, vol. I, 1928. This book contains a chapter on the manufacture of potato starch by Dr. Eugene Preuss which is illustrative of the technique used in Germany.

EYNON and LANE, Starch, Its Chemistry, Technology and Uses, 1928.

remarkably well. It is somewhat sensitive to frost and has a fairly long growing season, which confines planting to the warmer areas.

The average annual production of sweet potatoes in recent years has been between 60 and 70 million bushels, although over 80 million bushels were raised in 1929, with a value close to 80 million dollars. Large quantities are grown for shipping purposes, but home uses take the larger portion of the crop. The sweet potatoes are very irregular in size and shape and thus many do not meet standards for shipment. Some of these are used locally for human consumption, but they are also valuable for swine foods and for starch products. There are 22 states which grow considerable quantities of sweet potatoes, although North Carolina,

TABLE 22.—SWEET-POTATO PRODUCTION, UNITED STATES*
(1,000 bu.)

State	Average 1928–1932	1934	1935
North Carolina..	6,819	8,856	8,000
Georgia.........	6,769	7,120	8,010
Alabama........	6,368	7,614	6,900
Mississippi......	5,663	7,526	5,888
Tennessee.......	5,357	6,180	4,720
South Carolina..	4,569	4,428	5,192
Louisiana.......	4,950	5,840	6,512
Texas..........	4,734	3,300	6,390
Virginia........	4,316	3,910	4,060
Arkansas.......	2,176	1,620	1,820
United States.	63,841	67,400	69,853

* Yearbook of Agriculture, 1936.

Georgia, Alabama, Mississippi, Tennessee, South Carolina, Louisiana, and Texas are outstanding in this respect. The five first-named states produce about half the national crop. A greater total crop could be grown without difficulty, but markets for larger crops are not available.

The plant is usually started in hotbeds by planting old sweet potatoes from which shoots can be taken after a few weeks. These are later transplanted in the open. The field plants are subject to numerous diseases including blackrot, *Ceratostonella*, stem rot, *Fusaria*, root rot, *Plenodomus*, and soft rot of fungous origin, mosaic disease which is caused by a virus, and root knot, a malfunction caused by nematodes.[1] Among the insect pests are weevils, beetles, and the sweet-potato borer. The most widely grown varieties, according to Jones and Rosa,[2] include Yellow Jersey, Nancy Hall, Porto Rico, and Southern Queen.

[1] HARTER, L. L. and J. L. WEINER, *U. S. Dept. Agr. Tech. Bull.* 99, 1929.
[2] JONES, H. A., and J. T. ROSA, Truck Crop Plants, 1928.

The potatoes should be harvested before frost if possible and may be plowed out or dug by hand.[1] They are much more easily subject to injury than are white potatoes, and therefore less adapted to harvesting machinery, although such equipment has been used. The product keeps better if taken from the ground in dry weather so that the adherent soil quickly loses water and becomes easily removable. After harvesting they may be graded immediately and sent to market, or prepared for storage. Bruising is very injurious, therefore every precaution should be taken to prevent injury. In the warmer parts of the South, pits or cellars for storing are often used, while well-adapted wooden storage buildings are necessary in the colder areas. Very large losses occur because of improper control of storage conditions combined with carelessness in harvesting. The losses may be cut down to a great extent by storing the sweet potatoes at high temperatures, about 85°F., and high relative humidities, *i.e.*, 90 per cent, for 10 to 15 days, during which period good ventilation is essential.[2] This causes drying of the exterior of the roots, thereby cutting down fungus invasion, as these microorganisms propagate very rapidly in the liquids set free on bruised and cut surfaces unless the wound heals and new tissue cells develop. This warm-storage process is known as curing or sweating. While appreciable moisture losses result, the sweet potatoes are externally toughened and stand long storage subsequently with lower damage than otherwise could be expected.

After the sweating is completed, the plants may be stored at 50 to 55°F. for several months without excessive losses. The use of lower temperatures for any greatly extended time may increase the susceptibility to fungous rots which cause most of the damage. During the curing period and subsequent storage the roots are undergoing metabolic processes which cause corresponding changes in the starch and sugar content of the plant. During the first few months of storage there appears to be a conversion of starch to monosaccharides which apparently revert to some extent to give increase in starch in the later months of storage.

The canning of sweet potatoes has been carried on for about 50 years, although this industry has not reached the proportions which were at one time prophesied. The total annual pack has amounted to over 7,000,000 cases in some years but is often much smaller. In canning operations it has been found advantageous in handling if the sweet potatoes are cured as above described.

One of the methods of using culls and misshapen potatoes which has received considerable attention is in starch making. As has been stated

[1] Beattie, W. R., *U. S. Dept. Agr. Farmers' Bull.* 324, 1908.

[2] Thompson, H. C., *U. S. Dept. Agr. Farmers' Bull.* 1442, 1925. Revised, 1934, by V. R. Boswell and J. H. Beattie.

elsewhere, large quantities of white-potato starch are imported for use in the textile industry. Just as Maine especially uses culls and white potatoes for starch making, there now seems a possibility that the great surpluses of sweet potatoes may also be used in a similar manner. In 1934, one plant subsidized by Federal funds was started for this purpose. In addition to starch, there may be produced dextrins, which are adhesives and may be used for postage-stamp adhesives and other purposes, table sirup, and sugars for fermentation raw materials. At present however, "blackstrap" cane-sugar molasses is a cheaper source of fermentation alcohol than sweet-potato sugar.

Methods for such utilization have been worked out by Balch and Paine of the Carbohydrate Division of the Bureau of Chemistry and Soils.[1] While the methods were somewhat similar to those used for white potatoes, the yellow pigment of the sweet potato required the use of sulphur dioxide and other special treatment to make a satisfactory product. According to these authors, sweet potatoes are used as a source of starch in Japan, Burma, and Brazil.

Another means of conservation which was used for sweet potatoes, especially during the World War, involved the dehydration of the sliced product. While this dried material could easily be rehydrated and served as an appetizing and nourishing food, it has not become a commercial product. Sweet-potato flour has been made by grinding the dehydrated slices and also by drying the cooked crushed potato in a thin film on heated rolls. Such flour was found to combine with wheat flour and corn meal to make excellent bread, cake, and other baked foods, but it is extremely hygroscopic and tends to form a solid mass. So, except in emergencies, the product has not proved of popularity sufficient to be commercially successful.

The vast potentialities of sweet potatoes are, at present, hardly tapped as a raw material for food products or in industry and the latent possibilities of this crop as a food and as a source of commercial materials deserve further attention.

TOMATOES (*Lycopersicum*)

Tomatoes, although truly a fruit, are the most valuable vegetable crop in America with the exception of potatoes, and the popularity of tomatoes as a part of the American diet is rapidly growing. Tomatoes are raised in practically every part of the United States: in large truck gardens for distant markets, as an intensive crop for canning, on the small farm for local distribution, and in the back-yard garden for the individual family.

[1] BALCH, R. T., and H. S. PAINE, *Ind. Eng. Chem.*, **23**, 1205, 1931.

The tomato plant is an annual, belonging to the Solanaceae, or nightshade family, to which the potato also belongs. Its growing season is of such length that in many areas the seeds are planted indoors and later transplanted in the field. The fruit is in reality a large berry high in water, but with delicate pulp and containing malic acid, sugar, and heat-stable vitamins. It is particularly esteemed for its fine, characteristic flavor, attractive colorful appearance, and healthful properties. It is used to a large extent as a salad material in its fresh form and enjoys great popularity in its canned form as well as in catchup and other pickled materials. Tomato paste is another popular part of the diet of many of our inhabitants, particularly those of Mediterranean descent. In recent years canned tomato juice has made its appearance as a breakfast drink which has won great popularity and will doubtless be increased in consumption as time goes on. A modification of this is the "tomato cocktail." The common cultivated tomato is *Lycopersicum esculentum*, of which there are more than 175 varieties offered by seed dealers according to Robbins.[1]

A monograph, Descriptions of the Types of Principal American Varieties of Tomatoes, by Bowell and 10 collaborators[2] in various states, contains the very complete descriptions of nine varieties of tomatoes which are said to include probably 90 per cent of all the tomatoes grown in the United States. Those varieties are Earliana, Bonny Best, Gulf State Market, Globe, Marglobe, Early Detroit, Greater Baltimore, Stone, and Santa Clara. The latter three varieties are cited as being grown primarily for canning purposes.

According to Parsons[3] the Southern producing sections favor the Marglobe, Globe, Acme, Beauty, and Early Detroit varieties, while in the North Central States, Marglobe, Bonny Best, John Baer, Greater Baltimore, Acme, and Stone are the most widely grown as the main crop. In Eastern Texas, Acme, and Early Detroit are popular, while in California the Stone which was formerly popular is being supplanted by Marglobe and other varieties.

The tomato is subject to numerous diseases, caused by both bacteria and fungi. Some of these, as for example damping-off and wilt disease, occur during growth, destroy the plant or affect the yield as well as the quality of the product, while others, especially those of fungous etiology, are more apparent during harvesting and transit to distant markets and affect the ripening fruits. Certain of the fungous diseases which are caused by seed-borne microorganisms may be lessened by soaking the seed in solutions of mercuric chloride or other fungicides previous to

[1] ROBBINS, W. W., Botany of Crop Plants, 1931.
[2] BOWELL and others, *U. S. Dept. Agr., Misc. Publ.*, 160, 1933.
[3] PARSONS, *U. S. Dept. Agr. Farmers' Bull.* 1291.

planting. Some field diseases may be partially controlled by rotation of crops, avoiding the use of infected areas, or by spraying. One spray material used for this purpose is Bordeaux mixture (copper sulphate and quicklime).

Some wilt-resistant strains of tomatoes have been developed, such as Marglobe, Marvana, and Marvel.

Among the more serious tomato diseases are Septoria leaf spot, wilt disease, early blight, late blight, mosaic, tomato yellows, Fusarium wilt, bacterial canker, and nailhead spot. Late-blight rot is a serious market disease believed to be caused by a fungus closely related to, if not identical with *Phytophthora infestans* which attacks potatoes. It causes great damage to the plants in certain areas, and fruit from infected plants may undergo very rapid and extensive damage in transportation although apparently normal when harvested. This disease was particularly prevalent in Eastern states from 1920–1925 and later in the West.[1]

TABLE 23.—TOMATOES
(1,000 bu.)

State	1926	1929	1930
Florida	1,949	3,063	2,371
New Jersey	2,520	2,255	2,030
Texas	1,332	2,084	3,293
California	2,120	1,655	2,448
Mississippi	1,406	1,658	1,326

Another malady to which tomatoes are subject during shipment is nailhead spot, which is characterized by the appearance of small circular, slightly depressed brown spots on the surface which resemble nailheads. This disease is particularly troublesome in tomatoes shipped from the South to the larger markets.

Tomatoes are usually picked when the vines are dry in order to lessen the transmission of lead spot, blight, and similar diseases from vine to vine by the pickers.

The large production areas are so distributed that tomatoes may be obtained fresh the year round, if one includes hothouse tomatoes grown in the northern districts. For instance, beginning in the month of December, tomatoes are shipped from the east coast of Florida. As the season progresses, the shipping district shifts to western Florida, then to Texas and Mississippi, later to Tennessee, Ohio, Maryland, and New York. By this time the native crop of the other Eastern and Northern states is ripe, and after the frosts come in these areas, the Central section

[1] RAMSEY and BAILEY, *U. S. Dept. Agr. Circ.* 169. 1931.

of California supplies the markets. During the early spring, tomatoes are also imported from Mexico and the West Indies.

Table 23 shows the production of tomatoes for market in some of the leading tomato producing states.

The principal tomato-growing regions which produce this crop for food manufacture, such as for canned tomatoes, tomato juice, catchup, and other tomato products, had the production devoted exclusively to manufacturing purposes in recent years, as is shown in Table 24.

TABLE 24.—PRODUCTION FOR MANUFACTURING PURPOSES
(Tons)

State	1927	1930	1934
Indiana	163,400	395,000	315,400
California	178,300	336,000	291,500
New Jersey	156,000	258,000	122,800
Maryland	151,400	93,000	184,000
New York	70,600	77,500	119,200

Besides those states mentioned above, Ohio, Missouri, Delaware, Illinois, Kentucky, Tennessee, Pennsylvania, Virginia, West Virginia, and Utah are important producing states.

Tomatoes are picked ripe for canning and manufacture. In this condition they are firm and pink to deep red in color. If tomatoes are to be consumed within a few days, they are picked in the pink stage, that is, when about three-quarters of the surface is pink. Shipment to distant markets necessitates picking the tomato when it is fully grown, but has not commenced to change color (mature green stage). The tomatoes are picked by hand, using a twisting motion which separates the tomato from the stem, leaving the calyx attached to the fruit.

An extensive investigation of the effect of various temperatures on the storage and ripening of tomatoes conducted by Wright and others[1] showed that proper control of temperature was of great importance and brought out the following interesting conclusions: The storage of tomatoes for optimum results depends on the stage of maturity of the fruit when picked and the results which are desired. In certain instances it is desired to store firm fully ripe tomatoes in which case temperatures of about 55°F. are likely to be most satisfactory. If the object is to accelerate the ripening of the fruit, temperatures of 60 to 70°F. are preferable, higher temperatures than these being favorable to overripeness and very rapid decay simultaneously. Tomatoes which have begun to turn or show color may be ripened with almost normal results in 50°F. storage

[1] WRIGHT, PENTZER, WHITEMAN, and RISE, *U. S. Dept. Agr. Tech. Bull.* 268, 1931.

rooms, but if the temperature is 40°F., immature tomatoes will not ripen. For slow ripening storage temperatures of 55°F. are best.

Mature green tomatoes may be stored at 40°F., or even exposed to temperatures as low as 25°F. for short periods of time (less than a day), and subsequently ripened when exposed to higher temperatures, although the time of ripening is somewhat lengthened.

Ripe tomatoes may be kept satisfactorily at 32°F. for a week or more, but they deteriorate rapidly when stored at higher temperatures.

According to the Consumers Guide, vol. 2, No. 19, 1935, published by the U. S. Agricultural Adjustment Administration, tomatoes are sometimes treated with ethylene gas in freight cars or at terminal markets to accelerate the chemical changes in the pigment, known as the degreening of the fruit, but this treatment is not extensively used. It is not believed to affect the flavor.

Tomatoes, unlike potatoes and apples, are not well adapted to extended cold storage, hence, instead of storing tomatoes for long periods of time, resort is had to canning or to the fairly immediate consumption of the fruit.

After a preliminary process of grading the freshly picked fruit according to the size, smoothness, firmness, and ripeness of the tomatoes, they are wrapped in papers and packed in baskets and boxes, if destined immediately for market. A 4-qt. basket serves as the principal commercial container for these tomatoes. Six of these baskets fill a crate known as the carrier. It is also customary to employ four-basket flats, 12-qt. and ⅝-bu. baskets, and a 30-lb. bag (California). Many tomatoes appear on the market wrapped in soft tissue paper. Tomatoes which are shipped a long distance seem to stand up better when so wrapped, but there are serious objections to the practice of wrapping tomatoes. Chief among these are the facts that the wrapper may prevent proper ripening; it holds moisture, thus favoring the growth of microorganisms, and it is relatively expensive.

In addition to tomatoes grown outdoors, there has been a great increase in the production of tomatoes under glass, *i.e.*, in hothouses or in glasshouses, in the past 30 years. This system has become very common especially in New England, Pennsylvania, Ohio, New York, and Illinois. Tomatoes are more difficult to grow than the other two most common forced crops grown under glass, lettuce and cucumbers, but during the off seasons growers compete successfully with distant areas which harvest only partly ripened fruit grown in the field and must ship the product hundreds of miles. Much greater care must be taken to prevent insect and microbic invasions, as well as in governing physical and soil conditions in order to get yields sufficient to afford profitable returns. The product must also be carefully packed in market con-

tainers suitable for convenient handling. In New England eight cartons of 6-lb. capacity are commonly packed in a standard bushel box.[1]

Federal Definitions of Tomato Products.—Tomato puree, tomato pulp, is the product resulting from the concentration of the screened or strained fleshy and liquid portions of ripe tomatoes, except those portions from skin and core trimmings; with or without the addition of salt. The product contains not less than 8.37 per cent of tomato solids.

Tomato paste, salsa di pomodoro, "salsa," is the product resulting from the concentration of the screened or strained fleshy and liquid portions of ripe tomatoes, except those portions from skin and core trimmings: with or without the addition of salt, and with or without the addition of basil. The product contains not less than 22 per cent of tomato solids.

Heavy tomato paste, "concentrate," is tomato paste containing not less than 33 per cent of tomato solids.

Canned tomato juice, "tomato juice," is the unconcentrated, pasteurized product, consisting of the liquid, with a substantial portion of the pulp, expressed from ripe tomatoes with or without the application of heat and with or without the addition of salt.

Tomato catchup is the concentrated product made from the pulp and juice of ripe tomatoes (exclusive of skins, seeds, and cores), vinegar, salt, spice, and other seasoning, sugar and/or dextrose.

Products manufactured from tomatoes will be discussed in greater detail in later chapters.

CABBAGE

(Brassica oleracea)

The cabbage is a plant capable of growth in the wild state, yet it has been cultivated at least since the Egyptian and Roman eras. It is a common crop plant in Northern Europe and the British Isles and thrives in areas of high humidities and relatively low temperatures. Our coast states and regions adjacent to the Great Lakes are favorable from the standpoint of climate and soil. Cabbage may also be grown satisfactorily at high altitudes as it is fairly resistant to frost when approaching maturity. If grown in rich soil and carefully cultivated, it is possible to harvest 15 or more tons to the acre.

Cabbage has attained more attention and increased popularity since the advent of knowledge concerning vitamins as it has valuable properties as an antiscorbutic, containing considerable vitamin C which is particularly prevalent in the greener leaves. Its use as an antiscorbutic has been recognized for many years by sailors, and even in the days of Rome cabbage was used as a medicinal agent.

[1] BEATTIE, *U. S. Dept. Agr. Farmers' Bull.* 1431, 1930.

Cabbage is one of our most important green vegetable crops and attains wide usage in its boiled form, or raw, as cole slaw and a constituent of salads. A large quantity of certain types of cabbage is grown each year for the manufacture of sauerkraut. The plant is widely grown both as a general farm crop and as a truck-garden specialty. In the Southern states two crops are often grown in a year. Large quantities of newly harvested cabbage are shipped from Texas and Florida during the earlier months of the year to the great markets, followed as the season progresses by the crop of Alabama, Mississippi, Louisiana, South Carolina, and Virginia. The late (or winter) crop originates principally in New York, Wisconsin, Colorado, Michigan, and Minnesota and is used both for market and for sauerkraut. New York is by far the greatest producer of cabbages and accounts for about one-fourth of the total quantity raised in this country.

There are several special insect enemies of the cabbage, including the harlequin cabbage bug, the cabbage worms, and the cabbage aphis or "louse." Before heading, the worms may be controlled by the use of paris green or lead arsenate. Contact insecticides such as kerosene emulsions are helpful for the others. The harlequin bugs are most often picked from the heads by hand. The most serious plant disease attacking cabbage is known as clubroot, a malady produced by slime molds. The best way of eliminating it is by rotation in the use of land and by securing seed free from infection. The disease also may be propagated in turnips, mustard, and rape as well as cabbage. Cabbage is also subject to a soft rot of bacterial origin.

There are numerous varieties of cabbages, each of which is subject to a great variation under different soil and climatic conditions. A nitrogen deficiency in the soil is said to cause lighter greens in cabbage coloring with some varieties. Phosphorus or potash deficiencies tend to produce bronzed tints in the leaves. The principal American varieties now grown are Early Jersey Wakefield, Charleston Wakefield, Copenhagen Market, Early Winegstadt, Glory of Enkhuizen, All Seasons, Late Flat Dutch, Danish Ballhead, and Wisconsin Hollander.[1]

According to the U. S. Standards for Cabbage as of 1934[2] U. S. No. 1 grade should consist of heads of cabbage which are of one type and of reasonable solidity; which are not withered, puffy, or burst, and which are free from soft rot, seed stems and from damage caused by discolorations, freezing, disease, insects, or mechanical or other means.

The following table gives some indications of the commercial production of cabbage in the more important states. In addition to these

[1] A complete description of these varieties of recent origin. *U. S. Dept. Agr. Misc. Pub.* 169, Descriptions of Types of Principal American Varieties of Cabbage, March, 1934.

[2] *U. S. Dept. Agr. Bur. Agric. Econ.*, Sept. 1, 1934.

quantities there are many tons unreported grown on general farms and stored there until consumed by human beings or used as a winter green feed for poultry or stock.

TABLE 25.—COMMERCIAL PRODUCTION OF CABBAGE, UNITED STATES*
(Tons)

State	1915	1920	1926	1929	1934
New York	359,000	319,825	329,000	282,600	306,000
Wisconsin	133,650	128,340	127,600	129,200	186,000
Texas	13,500	78,725	82,900	118,300	212,000
Virginia	56,400	45,450	23,900	42,900	26,000
Florida	25,800	61,200	22,000	39,000	64,000
Louisiana	7,500	17,865	20,500	38,700	18,000
New Jersey	13,200	12,388	41,400	37,500	33,000
California	29,800	58,925	42,100	31,900	31,000
Colorado	39,960	57,400	43,800	34,000	30,000
Ohio	27,300	27,238	23,600	28,000	31,000
South Carolina	20,700	16,764	30,500	31,100	13,000
Total, United States	....	......	1,036,500	1,069,400	1,213,300

* Yearbook of Agriculture, 1935.

The late varieties of cabbage will keep in good condition for several months if stored at low temperature, while the early varieties are usually marketed soon after harvesting. Early cabbages from Florida and Carolina are shipped in crates, while Virginia uses barrels. The late varieties to be used for sauerkraut or winter storage require careful handling to avoid bruising. They are frequently stored in large warehouses provided with bins or shelves. Temperatures close to 34°F. are desirable because of high water content, but lower temperatures are dangerous.

TABLE 26.—CABBAGES: PRODUCTION IN SPECIFIED COUNTRIES * 1932

Country	1,000 Long Tons
France	7,824
Germany	1,085
Spain	954
Czechoslovakia	466
Italy	299
Rumania	290

* International Yearbook of Agriculture, 1932–1933.

Good ventilation is essential and the condensation of moisture on the cabbage must be avoided.[1]

European production is also very large as shown by Table 26.

[1] CORBETT, L. C., *U. S. Dept. Agr. Farmers' Bull.* 433, 1930.

BEANS (*Phaseolus vulgaris*)

Beans are members of the Leguminosae, the pea or pulse family, which from the standpoint of food supply is exceeded in importance only by the cereal grains. In addition to their importance in this respect these plants have the unique ability of using nitrogen from the atmosphere by living in a symbiotic relationship with nitrogen-fixing bacteria. These microorganisms cause the development of beneficent nodules or tubercles on the roots of the legumes and multiply greatly in them, and these are of distinct benefit as they increase the nitrogenous content of the soil, in addition to giving help to the associated plant. Numerous seeds of the legumes are now inoculated with these types of bacteria before planting as thereby the resulting crop is increased and the ground left in better condition after harvest.

There are many varieties of beans used for food purposes, the best known being the common or "navy beans" and the many strains of "horticultural," lima, and kidney beans, which may be grown for green "snap" or "string" beans. If allowed to ripen on the vines they gradually become dried and may be preserved indefinitely in this condition. One of the most common methods of preserving green beans is by canning, while New England's favorite dish of baked beans and pork using dried beans as the raw material is now canned extensively.

The cultivation of beans on this continent had apparently been going on for a long time before the first visit of Columbus. Later their cultivation became common in Europe where they were probably introduced from America. Beans may be classified in a number of ways, from the standpoint of botany, method of cultivation, use, or otherwise. In the admirable treatise on The Beans of New York by Dr. V. P. Hedrick[1] and his colleagues at the New York State Agricultural Experiment Station, beans are arranged in six groups, Pole Garden Beans, Bush Garden Beans, Field Beans, Horticultural Beans, Lima Beans, and Runner Beans.

The beans commonly used for market and canning purposes are generally twining plants growing to a height of 5 to 7 ft. if of the pole varieties, or if of the bush type, to about 1 ft. in height. There are several hundred varieties, varying in size, shape, and color of both the pod and the beans.

Beans are subject to a number of diseases including blight, caused by *Bacterium phaseoli;*[2] wilt, which is due to *B. flaccumfaciens;* anthracnose caused by *Colletobuchum lindemuthamum;* rust which is caused by *Uromyces appendiculatus;* and root rot, the causative agents of which are

[1] HEDRICK, V. P., W. T. TAPLEY, G. P. VAN ESELTINE, and W. P. ENZIE, The Vegetables of New York, vol. I, Part II, The Beans of New York. Report of the New York State Agr. Exp. Sta. for the year ending June 30, 1931.

[2] ZAUMEYER, W. J., *U. S. Dept. Agr. Tech. Bull.* 186, 1930.

Fusaria. Other diseases to which beans are sometimes subject are bean mosaic; downy mildew resulting from infections of *Phytophthora phaseoli;* pod blight caused by *Diaporthe phaseolorum,* and bacterial spot which has as its causative agent *B. vignae.*

Among the insect pests which cause losses are the bean weevil, the Mexican bean beetle, bean thrips, bean aphis, and the bean fly.

Green beans are grown in practically every home garden, in thousands of truck gardens, and in enormous acreages for canning purposes. Shipments of green beans for the fresh vegetable markets have tripled in the past 10 years, and in 1935 over 13,000 carloads were so dispatched, of which some 9,000 carloads came from Florida. Over 190,000 acres were planted to snap beans in 1934, producing 13 million bushels for use in the green form and 67,000 tons for canning and other purposes.

Florida and New Jersey are the more important producers of snap beans for fresh consumption, while New York is the greatest raiser of snap beans for canning purposes. For these uses the beans are generally picked by hand from the vines as the pods approach the proper stage of maturity. Very recently, however, a machine has been developed to strip pods from the vines at the cannery.

Among the more prominent varieties of green beans used for canning are Stringless Green Refugee, Burpee's Stringless Greenpod, Giant Stringless Greenpod, Kentucky Wonder, 1000 to 1 Refugee. The varieties of waxbeans include Burpee's New Kidney Wax, Stringless Refugee Wax and Wardell's Wax.

TABLE 27.—SNAP BEANS FOR CANNING BY LEADING STATES
(Tons)

State	1926	1929	1930
New York	6,800	14,700	14,700
Maryland	3,000	14,300	7,800
Wisconsin	4,200	9,600	6,900
Colorado	2,200	6,900	7,800
Louisiana	400	2,500	5,800
Total, United States	41,600	91,000	84,900

Dried Beans.—The production of beans which are to be later dried and stored for cooking purposes is one of large magnitude. These beans have a very high dietary value because of their concentrated protein and carbohydrate content. Our annual crop amounts to more than 10 million 100-lb. bags, and in addition we usually import some from Mexico and Cuba.

The United States is the largest producer of dried beans, although Rumania, Italy, England and Wales, Mexico, France, Hungary, Bulgaria, and Japan are also important bean producers.

TABLE 28.—BEANS (DRY AND EDIBLE): PRODUCTION IN LEADING STATES*

State	Production, 1,000 bags†		
	Average 1927–1931	1933	1934
California....	3,412	3,520	3,675
Michigan....	803	3,519	3,244
Idaho.......	565	1,670	1,342
Colorado.....	384	1,204	279
New York...	797	842	891
New Mexico.	686	598	66
Wyoming....	293	335	250
Montana....	380	306	174
Nebraska....	51	115	68
Maine.......	68	73	62

* Yearbook of Agriculture, 1935.
† Bags of 100 lb.

The best known variety is the pea or navy bean which Michigan and California produce to the extent of over 300 million pounds a year. Western New York is also an important producing area of the same type beans which are used for "pork and beans."

The Great Northern variety grown in Montana, Wyoming, and Nebraska is used for home-baked beans. Pinto beans are pink with brown mottling and are grown in New Mexico and Arizona. Kidney beans which are brown in color are especially grown in New York. California raises large quantities of white-pea beans, also the larger lima beans, the black-eye bean or cowpea, and the pink beans esteemed by the Mexicans.

The beans of this sort are allowed to ripen and then the vines are cut by a sledlike machine with knives running under the soil. The vines are stacked to dry and later threshed to separate the beans from the pod. Then they are screened and subjected to airblasts to remove foreign material. Sometimes the beans are subjected to a polishing process.

LIMA BEANS (*Phaseolus lunatus*)

The lima bean is a close relative of the green bean, having somewhat the same habit but differs considerably in respect to the pods which are flat, broad, and tough. The seeds are large and flat and the pods inedible.

When the beans are grown for market they are usually picked by hand, but for the canneries the vines are cut. When grown for dry lima beans, the vines are cut before the beans are mature, dried and later threshed.

These beans are believed to have originated in Peru and were introduced here about a hundred years ago. There are three somewhat different types under cultivation, the Small Vieva or Carolina type, the Big Limas, and the Potato Limas which have seeds which are more spheroidal in shape. Among the varieties grown are King of the Garden, Leviathan, Small White, Challenger, Dreer, Carpenteria, Florida Butter, Burpee Improved, and Henderson.

Lima beans are not so extensively grown as green beans, although they command a higher price. In 1934 there were 580,000 bu. produced as green beans and 16,000 tons of dried beans. California is the largest producer of dried lima beans.

PEAS (*Pisum sativum*)

Peas are one of our highly regarded garden and crop plants which have been grown for many centuries. They are believed to have been cultivated in some forms as far back as the stone age, although the garden types are of somewhat more recent origin. There is evidence to indicate that they were first used extensively in the Mediterranean regions, and later their cultivation spread northward to France and eventually to England. The English colonists brought seeds with them to the Americas where green peas are still an extremely popular food.

Poland, France, and the Netherlands are large producers of green peas. They are also grown extensively in Japan, Yugoslavia, Spain, and the British Isles.

In addition to garden peas, which are important as truck crops or for canning and freezing purpose, there is another type called field peas. Field peas are primarily grown for stock food, pasturage for hogs, and for soil enrichment, as they are legumes. The seeds of field peas are usually colored gray or green and may be dotted with darker colors.

The garden peas may be divided according to growth characteristics as some grow tall and require stakes or brush to climb on, while others are intermediate between the former and the dwarf or low-bush types. Some have smooth seeds, while others are wrinkled. Among the more common commercial varieties are Alaska, Little Gem, Advancers, Telephone, Gradus, Senator, and Horsford Market Garden.[1]

Producers are divided into three different groups in addition to those interested in their home gardens and those growing peas primarily for

[1] HEDRICK, V. P., F. H. HALL, L. R. HAWTHORN, A. BERGER, The Vegetables of New York, vol. I, Part I, Report of the New York State Agr. Exp. Sta. for year ending June 30, 1928.

seed. These groups are: first, the truck farmer who grows peas for the fresh vegetable market; second, the grower who produces peas for the canneries; third, those primarily concerned with growing peas for dried peas.

The very early green peas for market come principally from Florida and the Imperial Valley in California with smaller amounts from Texas and sometimes Arizona. The next shipments come largely from other parts of California and in small quantities from Mississippi, South Carolina, Louisiana, and Alabama. The intermediate shipments come from North Carolina, and Virginia, followed by Maryland and New Jersey. Later relatively large shipments are sent from Colorado, New York, Idaho, Washington and, to a lesser extent, Oregon. When these harvest seasons have passed, the late crop comes from central California, and after a few more weeks from Arizona and the Imperial Valley. Thus it is apparent that green peas may be available at almost any season in the metropolitan markets, though the product may travel several thousand miles.

For canning, peas are grown largely in Wisconsin, New York, Maryland, Utah, and Michigan. Dried peas are produced principally in Washington, Idaho, Wisconsin, Montana, Colorado, and Michigan.

Peas are subject to a number of diseases,[1] including Ascochyta blight which may be caused by the following fungi: *Ascochyta pisi* Lib., *Mycosphaerella pinodes*, and *Ascochyta pinodella*. Bacterial blight of peas has as its causative agent *B. pisi*. Fusarium wilt is caused by *Fusarium orthoceras*. Root rot of peas may be caused by *Aphanomyces euteiches*, *Fusarium martii* and by other fungi. In addition, there are several pests of fungous origin such as Septoria blight, Powdery mildew, Downy mildew, and Anthracnose. Another disease of peas is pea mosaic caused by a virus. Parasitic eelworms in the warmer states cause a malady known as root knot. Insects which are common to peas include the pea aphis and pea weevil.

The harvesting of green peas must be conducted at the right state of maturity, otherwise the crop will be inferior in quality. Chemical changes take place rapidly with a decrease in the concentration of sugar and soluble nitrogenous substances and increases in starch.[2] As these changes take place at a faster rate when the peas are warm, even after they are picked, it is desirable to cool them before shipping and in transit. If destined for the cannery, the less time elapsing between harvest and canning, the better the product.

Market peas are hand-picked, while cannery peas are harvested by mowing the vines by machine, after which the vines are carried to the

[1] Harter, L. L., W. J. Zaumeyer, and B. L. Wade, *U. S. Dept. Agr. Bull.* 1735, 1935.

[2] Boswell, W. R., *Univ. Maryland Agr. Exp. Sta. Bull.* 306, 1929.

cannery where the peas are separated mechanically by a machine known as the viner. When picked by hand, several pickings may be made in

Table 29.—Peas (Green): Production in the United States*

	Average 1928–1932	1933	1934
	1,000 bu.†	1,000 bu.†	1,000 bu.†
For market	6,088	8,605	7,442
Production, for manufacture:	Short tons‡	Short tons‡	Short tons‡
Maine	1,130	1,320	2,330
New York	22,990	14,320	13,280
Pennsylvania	1,520	1,650	3,000
Ohio	3,090	1,420	1,540
Indiana	5,790	1,940	2,610
Illinois	11,190	7,260	2,070
Michigan	6,710	4,550	6,390
Wisconsin	81,830	54,870	71,120
Minnesota	10,800	9,400	5,800
Delaware	1,690	1,960	3,010
Maryland	9,330	9,040	14,850
Montana	3,580	2,790	2,620
Colorado	2,700	1,960	3,430
Utah	11,710	9,070	11,020
Washington	2,190	5,120	9,030
Other states	5,820	10,270	12,670
Total	182,070	136,980	164,770

* Yearbook of Agriculture, 1935.
† Bushels containing approximately 30 lb., unshelled.
‡ Shelled.

order to have all the peas at just the right stage of maturity. Sometimes the vines are pulled and all the pods picked from the vine, a procedure which gives far less uniformity in the peas unless they are subsequently carefully graded as to maturity. More recently viners have been situated near to large pea-growing acreages in order to reduce the distance the vines must be transported. The shelled peas are then transported in speedy trucks to the cannery. Delays in transit must be avoided as shelled peas deteriorate in quality much more rapidly than when in the pod or on the vine. Later the vines may be used for stock feed or ensilage.

The time of harvest depends on the locality and the market. Southern and Southwestern peas are shipped fresh to New York during much of the winter, while in the canning regions the season lasts in various

areas from May to the middle of August. As the canning crop is harvested from the field by taking all the peas at one time, it is highly desirable to plant peas that ripen uniformly, but plantings may be progressive, *i.e.*, different fields may be planted in sequence at short intervals in order to have the period for canning and harvesting extended. The cannery yield of cannery peas per acre is usually less than a ton, especially when high quality is desired.

Peas have been found to be a good source of vitamin C, ascorbic acid. When the peas reach maturity the ascorbic acid content begins to decrease. Unless they are stored at temperatures lower than 10°C., the vitamin C content diminishes appreciably in a few days.

TABLE 30.—CANNED PEAS: PACK IN THE UNITED STATES*
(1,000 cases)†

State	1923	1928	1930	1932	1934
New York...	2,541	2,222	3,164	1,021	1,124
New Jersey..	199	242	74	49	384
Ohio........	384	336	208	131	156
Indiana.....	367	427	564	412	262
Illinois......	586	617	1,560	1,149	184
Michigan....	392	542	880	291	644
Wisconsin...	6,691	9,248	10,492	3,346	6,743
Minnesota...	254	722	1,333	1,161	528
Maryland...	591	1,030	400	689	1,657
Utah.......	918	1,154	1,662	752	1,311
California...	239				
Other states.	516	1,403	1,698	1,366	2,749
United States..................	13,948	17,943	22,035	10,367	15,742

* Yearbook of Agriculture, 1935.
† Cases of 24 No. 2 cans.

ASPARAGUS (*Asparagus officinalis*)

Asparagus is probably the most important of the perennial crops. The early market asparagus comes from California, South Carolina, and Georgia, the later crop from New Jersey, Illinois, Maryland, Washington, and Delaware. Large quantities of asparagus for canning are grown in the California valleys of the Sacramento and San Joaquin Rivers. Some is also canned in New York.

There are many varieties of asparagus, among which Colossal, Eclipse, Palmetto, Martha Washington, and Mary Washington are used for both market and canning purposes.

Three kinds of asparagus, depending upon the color of the spears, are prepared for market.[1] These are the green, green with white butt, and

[1] *U. S. Dept. Agr. Farmers' Bull.* 1646.

white asparagus. The green asparagus is obtained by cutting the spears off at the surface of the ground. Such asparagus dries out more quickly for it lacks the underground woody portion which acts as a check to the rapid loss of moisture. Green asparagus with a white butt is cut with a special asparagus knife in such a manner that a portion of the shoot comes from beneath the surface of the ground, with from 6 to 9 in. above the ground. In order to secure white asparagus which is grown particularly for canning, it is necessary to hill up the soil over the crowns, keeping out the light. The white asparagus is cut just as soon as the tips of the spears appear above the soil.

TABLE 31.—PRODUCTION OF ASPARAGUS FOR FRESH CONSUMPTION
(1,000 crates of 24 lb. each)

State	1929	1930	1933	1934	1935
California	1,341	1,791	1,990	2,297	1,701
New Jersey	882	1,000	950	1,036	930
South Carolina	288	340	380	361	361
Illinois	286	196	221	153	340
Maryland	208	202	221	356	253
Total (all states)	3,444	4,486	4,716	5,388	4,625

During the early part of the season it is only necessary to cut asparagus about once in three days. As the season progresses and it becomes warmer, growth is much faster and the asparagus has to be cut once and even twice a day at times in order to preserve its tenderness. After cutting, the asparagus should be kept in the shade and protected from excessive heat. It should be graded, bunched, and stored in a cool place as soon as possible. Grading is done according to the diameter of the spear. After cutting in 8- to 10-in. lengths, the stalks are tied in bunches. Usually the bunches are of approximately 1-lb. or 2- to 2½-lb. weights.

Chemical changes taking place in the spear, namely, a reduction in the sugar content and an increase in the tough fibrous material, render asparagus less edible. These changes take place most rapidly at high temperature, especially during the first 24 hours. The lower the temperature the better, since the changes are retarded, but freezing is undesirable. If asparagus is to be kept for some time after bunching, the bunches should be placed on end in cold water or on moistened moss with air motion at a minimum. Currents of warm air cause the stalks to elongate and chemical changes to take place which decrease their edibility.

The crates used in the shipping of asparagus depend very largely upon the section of the country where the asparagus is grown. Cali-

fornia, Georgia, and Carolina have a pyramidal-shaped crate of two compartments, each holding six bunches of the 2- to 2½-lb. size. A crate holding two dozen is popular in New Jersey. The bottoms of the crates are lined with paper (generally) and covered with damp moss, into which the bunches are packed butts down.

Asparagus is shipped by truck and express without the use of refrigeration for local markets. When carload shipments are to be sent a long distance, refrigerated cars are preferable.

Other uses for asparagus, in addition to use in fresh stock and to canning the products as such, include a concentrated paste and the manufacture of soup. A method has recently been proposed for dehydrating the butts trimmed off in bunching the market stock which later may be used for soups and flavoring.

SOYBEANS (*Soya max*)

One of the outstanding agricultural developments of the past two decades in this country has been the growing of soybeans, which are variously known as soya beans, soja beans, and stock peas. From a food standpoint the soybean crop has been one of the greatest importance in the Orient for centuries, but has only recently attained prominence in America. This plant is used not only for its seeds, but also for ensilage and as a hay and forage crop. There are said to be many hundred types, some of which vary greatly under similar climatic conditions. The identification of some of the 134 varieties now found in this country and classification of the same have been made by Etheridge.[1] Many varieties have seeds which somewhat resemble pea beans but are shorter and plumper. The color of the seeds ranges from yellow to green, brown, and black. The bitter flavor of these beans is quite different from that of ordinary beans, and a liking for their distinctive flavor usually must be acquired, as is the case with olives and grapefruit. There are many methods which are capable of removing this taste by relatively simple chemical treatment of the beans.[2]

Belonging to the legumes, the soybeans profit by the alliance of the nitrogen-fixing bacteria and therefore are beneficial to the soil by increasing its nitrogen content. The great usefulness of soybeans as a food is dependent on the high protein content of its seeds combined with a high fat content and a very low content of starch. The protein content varies from 30 to 50 per cent while the fat varies from 13 to 24 per cent, depending on the climate, soil, and variety, as shown in Table 33 result-

[1] ETHERIDGE, W. C., C. A. HELM, and B. M. KING, A Classification of the Soybeans, *Missouri Agr. Exp. Sta. Res. Bull.* 131, 1929.

[2] BAILEY, L. H., R. G. CAPEN, and J. A. LECLERC, The Composition and Characteristics of Soybeans, Soybean Flour and Soybean Bread, *Cereal Chem.*, **12**, 441, 1935.

TABLE 32.—SOYBEANS: PRODUCTION IN THE UNITED STATES*
(1,000 bu.)

State	Average 1927–1931	1933	1934
Ohio..........	618	336	408
Indiana........	1,919	1,740	2,400
Illinois........	4,350	4,350	9,519
Michigan......	21	24	21
Wisconsin......	23	69	60
Iowa..........	643	1,394	2,000
Missouri.......	1,077	1 518	878
Kansas........	72	94	25
Delaware......	246	378	442
Maryland......	71	78	90
Virginia.......	377	325	324
West Virginia..	36	36	26
North Carolina.	3,104	200	2,400
South Carolina.	339	250	126
Georgia........	165	90	94
Kentucky......	257	238	234
Tennessee......	727	128	105
Alabama.......	178	84	104
Mississippi.....	477	322	362
Arkansas......	240	160	204
Louisiana......	812	124	1,240
Oklahoma......	94	44	12
Total (all states).	15,845	14,982	21,074

* Yearbook of Agriculture, 1935.

TABLE 33.—CHEMICAL COMPOSITION OF SOYBEANS

Content	Minimum per cent	Maximum per cent	Average per cent
Moisture......................	5.02	9.42	8.0
Ash..........................	3.30	6.35	4.6
Fat..........................	13.50	24.20	18.0
Fiber.........................	2.84	6.27	3.5
Protein.......................	29.60	50.30	40.0
Pentosan.....................	3.77	5.45	4.4
Sugars.......................	5.65	9.46	7.0
Starchlike substances by diastase	4.65	8.97	5.6
P_2O_5........................	1.50	2.18	1.7
K_2O.........................	2.01	2.64	2.3
CaO..........................	0.49	0.63	0.5
MgO..........................	0.46	0.55	0.5
Weight per 1,000 seeds, grams...	40.00	248.00	150.0

ing from hundreds of analyses made by the Bureau of Chemistry, U. S. Department of Agriculture.[1]

Soybeans are also said to be excellent sources of vitamin A, good sources of vitamins B and G. When germinated, they contain vitamin C. They also exhibit some vitamin D content. It is also an excellent source of minerals.

The soybean has been grown in this country in a small way since 1804. Although it can grow under the same climatic conditions as corn and cotton, the capabilities of this crop have only recently been appreciated. As the soybean is a good dry-weather or hard-times crop, it has been used in the drought-stricken areas of our Midwestern states extensively. Some 2 million acres were seeded down in 1935. Another reason for its increasing popularity is its resistance to the chinch bug which attacks many of the forage grains and grasses. Illinois produced nearly half the total U. S. soybean crop in 1935 with Iowa, Indiana, and North Carolina next in importance. The total crop for 1935 in the United States was over 43 million bushels.

TABLE 34.—SOYBEANS: INTERNATIONAL TRADE*
(1,000 lb.)

Principal exporting countries	Average 1925–1929		1931		1932		1933	
	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports
China	3,731,214		5,074,744		2,302,596		12,744	
Principal importing countries								
Germany	0	,390,622		2,236,727		2,616,842	0	2,581,366
Japan	5,574	,105,825	483	1,220,267	230	.040,083	1,409	965,854
Denmark	0	394,965		523,993		503,955	0	516,224
United Kingdom	0	305,643		247.072		349,668	0	352,657
Sweden	0	166,799		68,753		19,856	0	126,947
Italy	42	97,395		88,820		47,409	0	13,916
Netherlands	1,192	58,510	182	70,952		91,897	177	86,518
United States		4,064		3,544		2,551	0	470
Total	6,808	3,352,823	5,665	4,460,128	3,918	4,672,261	1,586	4,643,952

* Yearbook of Agriculture, 1935.

The three largest producing regions of soybeans at present are Manchukuo, Chosen, and the United States. In 1931, China exported over 5 million tons of soybeans, principally from areas which have since become Japanese possessions. The largest importers are Japan, Germany, Denmark, Great Britain, and Sweden.

[1] BAILEY, L. H., R. G. CAPEN, and J. A. LECLERC, The Composition and Characteristics of Soybeans, Soybean Flour and Soybean Bread, *Cereal Chem.*, **12**, 441, 1935.

While much of the United States crop is used as stock feed and ensilage, millions of pounds of soybean oil go into butter and lard substitutes, mayonnaise, edible oil for cooking, paints and lacquers, soaps, and ink. About 30 million pounds of oil has been produced here in recent years. The oil is removed by the use of expellers similar to those used in the cotton-seed industry, by the use of hydraulic presses, or by the use of solvents, such as benzol. When solvents are used, the

USES OF SOY BEANS

- PLANTS
  - Green manure
  - Forage
    - Hay
    - Ensilage
    - Soiling
  - Pasture
- SEEDS
  - MEAL
    - Human food
      - Breakfast foods
      - Dietetic foods
      - Flour
        - Bread
        - Cake
        - Muffins
        - Biscuits
      - Infant foods
      - Macaroni
      - Crackers
      - Milk
    - Stock feed
    - Fertilizer
  - OIL
    - Glycerine
    - Explosives
    - Enamel
    - Varnish
    - Food Products
      - Butter substitutes
      - Lard substitutes
      - Edible oils
      - Salad oils
    - Waterproof goods
    - Linoleum
    - Paints
    - Soap stock
      - Soft soap
      - Hard soap
    - Celluloid
    - Rubber substitute
    - Printing inks
    - Lighting
    - Lubricating
  - FOOD PRODUCTS
    - Dried beans
      - Soy sauce
      - Boiled beans
      - Baked beans
      - Soups
      - Coffee substitute
      - Roasted beans
      - Vegetable milk
        - Cheese
          - Fresh
          - Dried
          - Smoked
          - Fermented
        - Condensed milk
        - Fresh milk
        - Confections
        - Casein
      - Breakfast foods
    - Green beans
      - Green vegetables
      - Canned
      - Salads

FIG. 18.—(*U. S. Department Agr. Farmers' Bull.* 1617, 1930.)

remaining material has many characteristics of flour. When pressed, the residue may be used as a food product resembling cheese or it can be treated to make adhesives, sizing for paper, or plastics.

One of the promoters of more widespread use of soybeans has been Henry Ford who has stimulated the industry by using soybean products in his automobile factories in the form of paints, finishing materials for steering wheels, and other equally diverse products. He has also introduced the soybean plant successfully in England where it may eventually serve the residents of the British Isles as well as it is coming to assist agriculture and industry in America.

The Chinese make many other soybean food products, including a milk from the ground cooked beans, cheese from the ground beans after treatment with calcium or magnesium salts, and soy sauce by fermentation.

In America soy flour has been found to be capable of use in macaroni products and as a constituent of ice cream and chocolate bars. When mixed with wheat flour in proportions up to 30 per cent, soybean flour is said to serve satisfactorily as a component for making bread, cake, and other products. Its phospholipin, lecithin, finds usage in the manufacture of margarine, chocolate, and confectionery, as well as in the textile industry. In Japan the oil is said to have attained use as a lubricant for engines after special treatment, also in the manufacture of rubber substitutes.

SWEET CORN (*Zea mays saccharata*)

Corn is one of the oldest known food plants of the American continent, so old in fact that even the tribal legends of the early Indian tribes have no historical background concerning its first usage. Remnants of our corn have been found by archeologists in the ancient dwelling places of the Aztecs and the Pueblos which indicate not only the many centuries it has been known, cultivated, and utilized, but also show its importance as a food. Charles Darwin, the eminent biologist, discovered a head of Indian corn on an island off the coast of Peru which he later found to be identical with other samples found in Peruvian tombs of a previous era. Columbus reported the cultivation of "maiz," probably corn in Cuba, in 1492, and other accumulated evidence indicates that corn had a widespread cultivation on this continent for many centuries. Its importance has long been recognized and a monograph was written on the subject in France by Bonafous as early as 1836.[1]

Sweet corn has been traced back some 600 years in Peru, but this variety gained less attention and not much was done concerning its especial cultivation previous to Colonial times. It has characteristics which make it admirably suited for eating in the immature or milk stage or for preservation at that stage for future use. The better known varieties have probably had their origin within the past two centuries. Some of the earliest known varieties were reputed to have been received from the Susquehanna Indians and planted in the Plymouth Colony in 1779. Others were obtained from the Iroquois Indians. One variety named Old Colony was developed between 1845 and 1850 in Somerville, Massachusetts, by a clergyman, the Rev. A. R. Pope.

[1] Tapley, W. T., W. D. Enzie, and G. P. Van Eseltine, Vegetables of New York, vol. 1, Part III, Sweet corn, 1934.

The majority of the varieties planted in considerable quantities previous to the present century had white kernels, although red-, black-, blue-, and brown-kerneled varieties were esteemed in some sections. The yellow kernels were less popular as they were looked on as "horse corn" rather than for human use. Shortly after 1902 the Golden Bantam variety became better known and appreciated, and owing to its influence the yellow-kerneled varieties have since attained greater consumption at the expense of the white. Both are widely grown for market as well as for canning purposes at present, but the red, black, and other colors are seen only occasionally.

There are quite varied preferences for distinct varieties in different market areas. In Eastern markets, particularly New York, the large white-eared varieties, such as Stowell's Evergreen, Long Island Beauty, and Late Mammoth, have been particularly popular. Some 150 market types of yellow sweet corn bearing different names are now planted, although there are only about 50 which appear to be distinct from each other.[1]

Sweet corn is now cultivated in all the civilized countries of the world where climatic conditions permit. A large part of the crop of the United States is grown for canning. The remainder is eaten on the cob in its fresh condition. Sweet-corn districts should be near their markets in order to deliver the product in optimum condition, because the corn loses its sweetness very rapidly after being picked, as the sugar is soon converted into starch. The more Northern states, especially those with warm days and cool nights, make the best corn-growing regions, for the corn remains tender and sweet for a longer period in the cooler climates. Accordingly, the great sweet-corn-producing states are Illinois, Iowa, Minnesota, Indiana, Maryland, Ohio, New York, and Maine, and to a lesser degree Michigan, Wisconsin, Nebraska, and Pennsylvania.

It is desirable to pick sweet corn when it is in the "milk stage," for at this stage it contains the most sugar. As corn remains on the stalk after the milk stage, the amount of sugar decreases while the starch increases. The same is true of picked corn, for the ripening processes of the ears continue and the fresh flavor is lost. The rate of loss of sugar is a function of temperature as well as of time. For example, Appleman found that at 30°C. around 50 per cent of the loss in sugar occurred within the first 24 hours of storage; at 20°C. about 25 per cent, and at 10°C. only about 15 per cent. Respiration accounts for a small percentage of the loss of sugar, but most of it is due to condensation to starch and other polysaccharides.

[1] For a detailed account of sweet corn, its varieties and descriptions, see The Vegetables of New York, vol. I, Part III, by Tapley, Enzie, and Van Eseltine. Report of the N. Y. State Agr. Exp. Sta. for the year ending June 30, 1934.

Because of the marked effect of temperature, the more Northerly states are best suited for corn canning because of their lower temperatures, although it is possible to plant late crops in the warmer areas so that the ears arrive at the milk stage in the cooler months. The Southern states also have more insect pests.

The degree of maturity of sweet corn is estimated from an examination of the corn husk, the color of the corn silk, and the fullness of the ear. It is necessary for the beginner to strip down a few ears in order to corroborate his judgment. The corn is detached from the stalk by a twist and a snap, placed in baskets or some suitable container, and carried to the end of the row where a pile is made. When the corn is to be carried directly to a cannery it may be put into a wagon immediately upon being picked. Care must be exercised not to allow corn to remain in deep piles for a long time, or to be packed too closely, for the rise in temperature affects the sugar content adversely, as noted above.

Corn may or may not be graded. For marketing, it is advisable to separate the small, medium, and large ears and use special boxes for each. The most common container for sweet corn is the bushel box. Into this is packed the corn which may vary in numbers of ears from three or four dozen up to six or seven or eight dozen ears of a small corn like the Golden Bantam. Crates, baskets, and bags are also used as containers for corn in some districts.

TABLE 35.—SWEET CORN CANNING*
(Commercial crop, in tons)

State	1926	1927	1928	1929	1933
Illinois	145,700	81,300	128,300	124,400	77,500
Iowa	151,400	61,500	99,600	108,600	41,100
Minnesota	73,400	50,200	85,800	101,000	98,600
Indiana	88,100	23,800	38,300	33,800	34,600
Maryland	74,500	49,500	53,200	50,300	35,300
Ohio	71,200	30,000	39,100	52,600	18,400
New York	60,300	32,500	32,400	36,900	28,300
Maine	46,900	23,100	30,200	46,000	29,900
Total (United States)	816,000	414,200	592,900	639,300	393,000

* Yearbook of Agriculture, 1930 and 1934.

NOTE: The consideration of corn as a grain is taken up in the chapter on corn.

The larger part of the sweet-corn crop, since it is so perishable by nature, is not transported long distances. The corn crop is raised as near as possible to its market. When, however, it becomes necessary to ship corn a considerable distance, this can be done by packing it in a well-ventilated container (box or crate) and transporting it in a refrigerator car. The bulk of the sweet corn is brought into the market by

means of motor trucks which cut down the transportation time for short hauls. The use of sweet corn for commercial canning represents an important part of this crop and in 1931 the apparent consumption of sweet corn for this purpose amounted to 12.6 lb. per capita.

Within recent years a small quantity of corn on the cob has been packed and quick-frozen for use during those months in which fresh corn is not available.

The European Corn Borer.—One of the most dangerous pests which afflict sweet corn is the borer, hence a statement regarding this source of damage is not out of place here.

The European corn borer is found distributed over Europe[1] and parts of Asia, as well as in North America where regions in the vicinity of the Great Lakes, in New York, and in parts of New England are particularly infested.

Stuart Vinal, in 1917, discovered the European corn borer in this country, to which it is believed to have been brought from either Austria or Italy between 1908 and 1909.

It was not until 1926 that the seriousness of the destructive attacks by corn borers became fully realized. At about this time the corn crop in southern Ontario was nearly completely destroyed and the states of Ohio and Michigan had been invaded, as well as the northeastern part of Indiana.[2]

The borers attack many other herbaceous plants which offer stems large enough for them to enter. The corn borer has been found feeding on over 200 varieties of plants, although corn appears to be preferred.

The corn borer passes the winter in the larval stage as a mature caterpillar or worm in the stems of the plants which have served as food. The borer, which is ¾ to 1 in. long, is located especially in the stalk just above the surface of the ground in winter, but may be found in "all parts of the stem and ear."

In the spring, the borer passes into the pupal stage, and emerges as a moth from June to August. The female moths lay their eggs in batches of 5 to 50 on the under sides of the leaves of the plants which are to serve as food for the young borers. A single female lays an average of 500 to 600, or more, eggs during one season. The rate of increase, however, is judged to be approximately 30-fold, or 5 borers multiply to approximately 150 in a season.

Eggs generally hatch in a week or less, according to the temperature, to produce young borers. The borers feed at first externally on leaves, but soon bore, principally into leaf stems or stalks. They feed thus as

[1] METCALF, C. L., and W. P. FLINT, Destructive and Useful Insects, McGraw-Hill Book Company, Inc., New York, 1928.

[2] Yearbook of Agriculture, 1927.

borers until they become mature, or fully grown, usually during August or September.

In most of North America, there is one generation a year of adult borers, but in New England there are two; the second generation appears in August or early September and the moths lay their eggs, the resulting larvae, or borers, developing in the late summer or early fall.

There are several methods of control in general use. Burning of the stalks, leaves, and refuse is one of the most effective measures in controlling the European corn borer. Plowing the corn refuse under is also effective, if the work is done thoroughly.

Control by means of improved corn-cutting equipment is of great advantage.[1] Approximately 10 per cent of the corn borers in the corn plant are located in the first 6 in. of the stalk above ground level. The corn binders in use before 1927 left stubble 4 to 6 in. high. A new type of corn-cutting apparatus which cuts the corn off within 2 in., or less, of the ground is recommended.

Late planting of the corn where the corn borer has only one generation a year is helpful. Rotation of crops is of value, as well as the destruction of weeds which may harbor this pest temporarily.

ONIONS (*Allium*)

Onions are members of the lily family, Liliaceae, grown for their underground bulbs, which have a more or less characteristic odor and flavor due to allyl sulphide. They have been cultivated for many centuries and are used as vegetables, for pickling and as seasoning for other food materials, especially sauces and soups.

From a commercial standpoint onions are an important food crop and rank in value only below potatoes, sweet potatoes, tomatoes, and cabbages. There are many American varieties as well as the different types of foreign origin such as the Bermuda, Spanish, and Italian onions which are less pronounced in flavor. The native varieties include Danvers, Southport, Wethersfield, Silver Skin, and Silver King.

There are two centers of onion production, the Southern states producing onions for the earlier markets in the winter or spring months while the more northern states raise the crops harvested in late summer or fall. As may be seen from Table 36, New York, Texas, Michigan, and California are the large onion-growing states.

In spite of the great quantities of onions grown in the United States, these vegetables are sometimes imported to the extent of several million bushels. Spain, Italy, Egypt, Chili, Bermuda, and Mexico furnish a part of our imports.

[1] Yearbook of Agriculture, 1928.

Insect pests of onions include thrips and maggots. Onions are subject to numerous fungous diseases in the field including smut caused by *Urocystis cepulae*, mildew (blight) due to *Peronospora schleideni*, leaf

TABLE 36.—ONION PRODUCTION BY LEADING STATES*
1,000 sacks†

State	Average 1928–1932	1933	1934
New York....	1,663	2,021	2,475
Texas.........	2,091	1,395	1,952
Michigan......	1,124	1,520	1,918
California......	1,626	1,336	1,204
Indiana........	1,410	756	484
Colorado......	924	652	533
Massachusetts.	606	693	783
Ohio..........	710	567	504
Idaho.........	381	395	811
New Jersey....	338	540	560

* Yearbook of Agriculture, 1935.
† Sacks contain 100 lb.

mold which results from dry soil and the attack of *Macrosporium parasiticum*. Purple blotch is caused by *Macrosporium porri*, and pink root has as its causative agent *Phoma terrestris*. Two rusts which sometimes occur are caused by *Puccinia porri* and *Puccinia asparagi*. White rot which invades the roots has *Sclerotium cepivorum* as its causative agent. A virus disease in onions called Yellow Dwarf was found in Iowa in 1928 and later elsewhere. Another parasite is Dodder which is a higher plant but one which depends on small onions and other plants for its food. Onions also have an affection known as root knot, caused by eelworms in the soil. In storage and transit, neck rot is a serious onion disease due to *Botrytis* spp. *Aspergillus niger* may cause black mold. *Colletotrichum circinans* causes a fungous discoloration known as smudge. A soft rot sometimes develops in bruised onions owing to bacterial invasion.[1] Onions are also subject to blemishes known as scorched-spot and bag-print, owing to chemicals in the fabric of the bag used for shipment which causes a reaction with onion pigments.[2] Ammonia from refrigeration systems and severe exposure to sunlight may also cause characteristic blemishes and discolorations.

Late onions are harvested as soon as possible after the neck of the mature onion bulb loses its stiffness sufficient to allow the top to fall over. It is advisable to permit the tops to dry out as much as they will, since this aids in preventing storage rots. Rain produces "stiff necks" which are marketed immediately rather than stored. In twisting or

[1] WALKER, J. C., *U. S. Dept. Agr. Farmers' Bull.* 1060, 1931.
[2] RAMSEY, G. B., *U. S. Dept. Agr. Circ.* 135, 1930.

cutting off the tops, at least 1 in. of neck is usually left so as not to expose the juicy tissue of the scales of the bulb. Care should be exercised not to bruise the bulbs since wounds serve as portals of entry for microorganisms.

The interval of time between harvesting and storing is a critical one for the onion grower, because the onions must be cured or undergo a sweating process which, if not satisfactory, favors rotting by bacteria and fungi. The onions are placed in crates which permit the free circulation of air, and then are stacked in a field or under sheds, depending upon the weather. Sunny dry weather is ideal, for under these conditions the moisture given off by the onions evaporates and disappears quickly. High humidity brings about the condensation of moisture within the crate, with added possibility of rotting. Rainy weather is detrimental to both harvesting and the curing. Since decay is such an important item in onion raising, care should be practiced in destroying diseased bulbs and tops after the harvest.

Hampers, bags, baskets, and crates are all common containers for onions. The main objection against the use of bags is that onions are easily bruised in them, and hence open to invasion by the bacteria and mold spores which are omnipresent.

Only sound bulbs which have been well cured should go into storage. That part of the crop which is fit for human consumption but not of the quality for storage should be marketed immediately after harvesting and curing. Low temperature and good ventilation are essential factors of good storage for onions. A uniform temperature of 32°F., or just a fraction below, is ideal for the bulbs, but great care must be employed to keep the temperature from falling below 28°F. for any considerable length of time, as the onions will freeze. Moisture is given off by the onions, hence it is desirable that the storage atmosphere must be dry. Careful regulation of the ventilation system and drying of the air is essential. Calcium chloride is used sometimes to remove moisture from the air. A dry cellar with a temperature kept between 32 and 35°F. is satisfactory as a storage place for onions. In packing the onions in the storage houses, ample room should be allowed between the crates for good air circulation.

Low temperatures are also important because they tend to prevent sprouting.[1] With some varieties, such as Southport and White Glove, unless the dampness is reduced, rooting is particularly likely to take place, according to various authors.[2,3,4,5]

[1] Boswell, W. R., *Proc. Am. Soc. Hort. Sci.*, 225–239, 1923.

[2] Cleaver, H. M., *Purdue Univ. Agr. Exp. Sta. Bull.* 393, 1934.

[3] Jones, H. A., and J. J. Rosa, Truck Crop Plants, 1928.

[4] *U. S. Dept. Agr. Misc. Pub.* 190, 1934. Handbook of U. S. Standards for Grading and Marketing Fresh Fruits and Vegetables.

[5] Thompson, H. C., Vegetable Crops, 1923.

CHAPTER VI

FRUITS

APPLES (*Pyrus malus*)

Apples have been known and appreciated as a food for many centuries. In legend, apples have become famous because of their inspiration to Sir Isaac Newton in his experiments on gravity. Regardless of legend, apples are one of the most popular and widely used fruits in the United States, being attractive not only because of the beauty of many varieties but also on account of the appealing flavors which so many varieties present.

Apples are extensively cultivated in the temperate zones and are raised in large quantities in the United States, Canada, Europe, South Africa, Northern India, China, Australia, New Zealand, and Tasmania. The United States is the largest producer and exporter of apples, with Canada and Australia the next largest exporters of this fruit. France is the largest European producer and exporter. The United Kingdom is the largest importer of apples. In 1932 the United States exported over 13 million bushels of fresh apples and 18,000 tons of dried apples.

Apples are the most common and most important fruit crop of the United States. Large portions of the annual harvest are utilized within comparatively short distances of the Eastern growing areas. The apples from Washington, however, have become very popular in the metropolitan areas because of size and color and because much more attention is paid to packing, grading, and merchandising the products from that region. The increase in use of other table fruits and fruit juices has given serious competition to apples in recent years, and the proper methods of handling and popularizing these products must be adopted by apple growers if their markets are to be retained.

There are many varieties of apples and in some instances there has existed a certain amount of confusion and duplication in nomenclature.[1] The seven most important New England varieties are the McIntosh, Gravenstein, Northern Spy, Delicious, Baldwin, Wealthy, and Rhode Island Greening. Some of the other apple varieties which have attained popularity elsewhere in this country include Rome Beauty, Stayman,

[1] RAGAN, W. H., Nomenclature of the Apple, *U. S. Dept. Agr. Bur. Plant Ind. Bull.* 56, 1905.

TABLE 37.—INTERNATIONAL TRADE IN APPLES*
(1,000 bu.)

Country	Average 1925–1929		1930		1931		1932		1933	
	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports
Principal exporting countries:										
United States	448	137	15.850	157	17,785	36	16,919	54	11,029	7
Canada	626	542	6,390	485	4,783	424	4,708	225	8,716	113
Australia	161	0	3,621	0	2,770	0	3,916	0	4,737	0
France	876	608	1,314	1,737	1,722	3,016	1,769	2,548	3,331	1,579
Italy	597	1	1,908	3	1,535	6	1,236	9	1,358	5
Netherlands	309	422	448	778	721	911	998	1,114	1,381	970
Belgium	122	303	1,005	704	486	964	1,927	618	1,282	980
Rumania	734	1	604	3	354	17	140	1		
Yugoslavia	783	2	2,688	2	865	5	1,999	1	343	
New Zealand	565	31	1,072	27	1,081	12	1,259	4	1,092	
Principal importing countries:										
United Kingdom	0	14,247		13,583	0	17,007		18,078		16,615
Germany		8,415	40	11,195	157	5,444	116	11,758		9,879
Sweden		754	150	683	0	829	0	799		4,449
Denmark		684	3	674	0	91	1	453	101	354
Irish Free State		469		449		475	7	517		401
Egypt		379	1	360		194	1	161		164
Norway		20[illegible]	0	170		210	0	14[illegible]		94
Brazil		191	0	114		146	0	134		
Finland		178	0	166		141	0	86		59
Cuba		96	0	80		58	0	46		
Poland		88	150	484		375		163		278

TABLE 38.—APPLE PRODUCTION IN THE UNITED STATES*
(1,000 bu.)

State	Average 1927–1929	1933	1934
Washington	32,306	29,240	32,300
New York	16,836	16,060	11,844
Virginia	12,914	10,900	9,275
California	9,839	9,333	6,500
Pennsylvania	8,909	7,293	8,554
Michigan	6,261	8,651	6,464
Ohio	6,653	4,380	4,032
West Virginia	7,001	4,200	3,630
Idaho	5,426	5,244	3,312
Oregon	4,981	3,500	4,938
North Carolina	3,386	5,254	3,525
Illinois	4,728	2,200	2,162

* Yearbook of Agriculture, 1935.

Winesap, Pippins, Grimes Golden, Jonathan, Spitzbergen, Arkansas, Russet, Ben Davis, and Yellow Newtown.

In addition to being well flavored, attractive in appearance, and nourishing, the apple contains vitamin C. According to Fellers, Baldwin apples are good sources of this vitamin and after 4 to 6 months' storage at 36°F. the loss in vitamin C was found to be only about 20 per cent.[1]

The state of Washington has become the largest producer of apples, owing in large part to ease of irrigation and to climatic conditions in the Northwest which are ideal for this crop, although apples are grown to some extent in practically every state. While the apple is a hardy plant, its blossoms are destroyed by frost, and apple orchards are often planted on elevated areas which are less subject to late frosts, in order to protect the blossoms as far as possible from such damage. Very severe winters may sometimes kill apple trees, owing to the low temperatures. The winter 1933–1934 was sufficiently severe in New England to winter-kill many entire orchards in that region, particularly those planted with Baldwin apples, for which New England has been famous. More hardy varieties in the same district survived, however. The best soil for apple orchards is good, well-drained, preferably calcareous soil. Manure, or fertilizers rich in nitrogen, such as nitrate of soda, and mulching are excellent for producing tree growth and heavy crops. Trees should not be planted too close together as it is desirable for as much sunshine to reach each individual tree as possible because of greater facility in nourishment and care. Proper pruning of the trees, especially thinning out the central branches, insures larger and better colored fruit. Established varieties of apples are propagated by budding and grafting.

Although there are many varieties of apples, they differ widely in those characteristics which are desirable in a food of this nature. Some have good flavor for a brief period, yet quickly decay or lack the qualities which make them desirable for continued consumption; some are grown because they keep well or can be shipped with only slight loss; some are excellent cooking apples, others juicy and fine-flavored table apples, and still others do not possess superior qualities for either cooking or eating, yet are desirable for general food purposes. In commercial practice it is not regarded as good technique to attempt to raise a large variety of apples. The successful growers usually discover that a few of the better known varieties should be cultivated and the special requirements of these carefully studied. Each agricultural region has certain varieties of apples which thrive best under local conditions and to which the taste of the people is educated.

[1] Fellers, C. R., M. M. Cleveland, and J. A. Clague, *J. Agr. Res.*, **46**, 1039, 1933.

In addition to climatic conditions, there are serious biologic problems to be met in the apple industry. Apple trees and the fruit itself are subject to many insect, fungous, and bacterial depredations. San José scale, numerous caterpillars, the codling moth, blights, scab, and fungous rots are a few of the enemies with which the orchardist has to contend. But insects and fungous diseases can generally be controlled by the application of sprays and dusts at the appropriate time.

In order to avoid the losses due to some orchard insects, various sprays are used. Among the sprays used effectively are certain arsenic compounds, such as basic lead arsenate and lead hydrogen arsenate, also known as acid lead arsenate. As these compounds may be lethal to man, or cause severe poisoning if ingested in sufficient quantities, it is often necessary to wash the fruit after harvesting to remove the arsenic left on the apples. Legal standards in various states and Federal regulations make this necessary for sprayed apples shipped in interstate commerce. The common treatment for arsenic removal and washing has utilized dilute hydrochloric acid or alkaline solvents. As the fruit itself may be injured by soluble arsenic as well as by hydrochloric acid and by alkaline solvents such as sodium carbonate, sodium hypochlorite, etc., the greatest care should be used in such operations and the fruit generously rinsed after such treatment.

There are a number of diseases of apples which appear while apples are in storage, although their origin may have resulted from conditions occurring in the orchard or during transportation. Often they may be traced to parasitic diseases, but certain physiologic abnormalities are known to develop under specific conditions of storage. The latter may be avoided in part by careful control of environmental factors in storage or transportation.

Formerly, many apple growers, in preparing their fruit for market, put it into barrels or boxes with no particular attention to grading or packing. Competition and modern demand have so altered this custom that most orchardists find it necessary to grade their fruit carefully according to quality and size and pack it in standardized boxes in an attractive manner. With the finest fruit, for table apples, each may be paper-wrapped.

As the apple is in demand for a large portion of the year, preservation by storage is of great importance. Storage should be in a well-ventilated, fairly humid place, with a temperature just above the freezing point of the apple. Only sound fruit should be placed in storage. The fungi causing rot will develop at low temperatures and any infested or rotten fruit is a potential menace to all fruit surrounding it. If not excluded when stored, it should be removed without delay on discovery, along with any bruised fruit. Careful picking of apples intended for storage does

much to prolong the life of the fruit. Any breaks in the skin, such as wounds made on apples by the finger nail or by breaking off the stem, are sources of infection and bad bruises are foci of infection or deterioration. By using corrugated paper liners in wooden containers many bruises and subsequent infections may be avoided.

Among the so-called storage diseases are alternaria rot, internal breakdown, internal browning, Jonathan spot, scald, soft scald, and bitter pit. Those which are due to fungi are minimized by care, harvesting, washing, and packing plus refrigeration in storage. Certain of the storage diseases are due to accumulation of gaseous metabolic products of the apples themselves. When good conditions of aeration and ventilation are available, these gases are removed, but in closed boxes and barrels they are likely to accumulate. One method of prophylaxis is to wrap the fruit in oiled paper or pack shredded oiled paper in the box or container. The mineral oil used on the paper has the ability of absorbing the gases and lessening such troubles. A comprehensive survey of the Market Diseases of Apples, Pears and Quinces has been recently published by Rose, Brooks, Fisher and Bratley of the Bureau of Plant Industry, U. S. Department of Agriculture, and covers the diseases, causes, and available information concerning their elimination.[1,2] As Great Britain is a large importer of apples which must come from long distances and incur great injuries in transportation as well as storage, much interest and study have been devoted to apple storage. Kidd and West[3] have shown that internal breakdown may occur to a greater extent if low temperatures close to freezing are used than at temperatures of 38°F. A summary of investigations of this nature in England, Wastage in Imported Fruit: Its Nature, Extent and Prevention, by Barker, indicates that diseases are likely to occur in apples originating in Australia, British Columbia, the United States, and Nova Scotia.[4] Those from Australia and British Columbia suffer particularly from internal breakdown. Overholser, who has conducted research on the shipments of California fruit to the Far East, found it possible to ship Yellow Newtown apples to Singapore, taking eight weeks, without the development of internal browning when an average storage temperature over 36°F. was used.[5]

It has been found that the blue-mold decay of apples packed in the state of Washington may be decreased by treating the apples with a

[1] Rose, D. H., C. Brooks, D. F. Fisher, and C. O. Bratley, *U. S. Dept. Agr. Misc. Pub.* 168, 1933.

[2] Brooks, C., J. S. Cooley, and D. F. Fisher, *U. S. Dept. Agr. Farmers' Bull.* 1160, 1930.

[3] Kidd, F., and C. West, Dept. Sci. Ind. Res., London, *Food Invest. Ann. Rep.*, 1923.

[4] Barker, J., Dept. Sci. Ind. Res., London, *Food Invest. Spec. Rep.* 38, 1930.

[5] Overholser, E. L., *Univ. Calif. Agr. Exp. Sta., Berkeley*, 497, 1930.

sodium hypochlorite rinse. Baker and Heald recommend for this purpose the treatment of apples by washing, then subjecting the fruit to a solution of sodium hypochlorite containing 0.4 per cent available chlorine for a period of one minute.[1] This method is reported to be more efficient than the use of sodium bicarbonate or sodium tetraborate or the use of chemically treated paper wraps. It is particularly effective against *P. expansum* as well as *P. italicum* and *P. digitatum*, each of which may cause spoilage of this nature. The same chemical treatment is also recommended for lowering the incidence of fungous infections in picking boxes and packing equipment which often serve as sources of severe contamination to the fruit.

Very recently it has been found of benefit to regulate the gases in the atmosphere where apples are stored. Carbon dioxide has proved very efficacious in lowering the incidence of fungous spoilage and has attained considerable usage in English storehouses. This method has also proved beneficial for ocean transport and has been utilized in some ships carrying fruit cargoes. Carbon dioxide has likewise proved a valuable adjunct in the refrigerated storage and transport of meats.

Apples have several well-recognized uses: as fresh fruit, for cooking in various ways, especially pies (tarts) and applesauce; for canning, and for making jellies, jams, and marmalades. Apple juice is the source of cider and cider vinegar. Pectin is an apple by-product used in the manufacture of jellies.

Canned apples are sold in large quantities to hotels, restaurants, and bakers. First-quality apples are not usually canned but only some of the best of the lower grades. Canning apples should have firm white flesh and should be of acid nature rather than of sweet character, as texture and flavor are important. Apples that lose their shape or darken much in color during the processing are undesirable. Apples for canning are washed, peeled, cored, trimmed, quartered, and passed into dilute brine to prevent oxidation and subsequent darkening. They are next blanched to destroy the oxidase system and drive off oxygen. Blanching is accomplished by the use of steam, immersion in 3 per cent boiling brine for a few minutes, the use of brine and vacuum, or by prolonged heating of the fruit in hot water. The blanched fruit may then be packed in cans with or without the addition of hot water or weak brine. The cans should be well filled.

Exhaustion of the air from the filled can is very necessary, since pinholing and corrosion due to malic acid and oxygen are reduced by such a procedure in combination with blanching. Rapid cooling after sterilization and inversion of the cans at frequent intervals do much to retard such troubles as corrosion which is most apt to occur at the surface of

[1] Baker, K. F., and F. D. Heald, *Washington Agr. Sta. Bull.* 304, 1934.

the liquid. Sterilization at 212°F. for about 10 minutes with agitation is generally sufficient if applied when the material is still hot, for the natural acidity of the fruit assists in the destruction of microbic life.

The canning of whole apples as "baked apples," whereby the whole apple, except the core which is removed, is cooked in a sugar sirup without removing the skin, has been successfully accomplished by a New England manufacturer.

Apples for the bakery trade are frozen in considerable volumes. In this case the apples are usually peeled, cored, and quartered, then packed in large cans or containers, sometimes in sirup, and frozen. Previous to packing the apples are in some instances placed in a bath of dilute sulphurous acid, made by passing (SO_2) sulphur dioxide gas into water, in order to prevent subsequent darkening of the tissue.

Apples, like many other fruits, and vegetables, are now quick-frozen in packages. This type of product may be used for the making of pies with a minimum of inconvenience to the domestic consumer.

Dried or evaporated apples and their production are discussed in the chapter on Dehydration.

TABLE 39.—CHEMICAL COMPOSITION OF APPLES*

	Per Cent
Water	84.1
Protein	0.3
Fat	0.4
Ash	0.29
Carbohydrates	
Total and fiber	14.9
Fiber	1.0
Sugar as invert	11.1
Acid (as malic)	0.47
Refuse	12.0

* ATWATER and BRYANT, U. S. *Dept. Agr. Bull.* 28, 1906.

CITRUS FRUITS

The principal citrus fruits of the United States are oranges, grapefruit, and lemons. Although limes, tangerines, kumquats, and others are citrus fruits, their commercial importance is negligible compared with the tremendous crops of oranges, grapefruit, and lemons which are shipped to metropolitan areas for consumption. In some recent years more than 120,000 carloads of these semitropical fruits have been shipped by rail, and other large quantities now are transported by trucks.

The popularity of citrus fruits has increased to a marked extent in the past two decades and the trends in food habits indicate that the future consumption of this type of fruit may be even greater. Citrus fruits were formerly used largely as table fruit or for cooking and desserts,

but the advent of efficient juice extractors has caused many American families to become large consumers of citrus-fruit juices. Citrus fruits have also taken their place in salads. The development of improved methods of citrus canning has enabled the preservation of these juices, and in some instances the pulp also, in tin as well as glass. Some of the juices have also been frozen and preserved in that state by refrigeration until marketed in distant areas.

All these factors have proved beneficial to the citrus growers, who have found it to their advantage in some areas to form cooperative associations. These organizations serve not only as a center for the handling of the products but also maintain up-to-date merchandising services in all the large cities and see that their products are properly distributed and advertised. Some of these organizations also have by-product plants which manufacture various commercial products from waste or cull fruit. Laboratories are maintained by the more progressive to find uses for such by-products.

TABLE 40.—CHEMICAL COMPOSITION OF CITRUS FRUITS*

Content	Grapefruit, per cent	Lemons, per cent	Oranges, per cent
Water	88.8	89.3	87.2
Protein	0.5	0.9	0.9
Fat	0.2	0.6	0.2
Carbohydrates plus fiber	10.1	8.7	11.2
Sugar (as invert)	6.5	2.2	8.8
Fiber	0.3	0.9	0.6
Ash	0.42	0.54	0.47
Acid (as citric)	1.69	5.07	0.68
Refuse	34.0	38.0	28.0

* *U. S. Dept. Agr. Circ.* 50, 1931.

Table 40 indicates the general composition of the more important citrus fruits. All are comprised largely of water, with only slight amounts of protein and fat. Their flavor is due largely to the presence of acid and carbohydrates and small quantities of characteristic volatile oils. The increased utilization of these products in the dietary has been due in part to the fact that citrus fruits are good sources of vitamin C. Recent nutritional studies indicate that the ingestion of citrus fruits containing citric acid tends to reduce the acidity of the blood somewhat because in the metabolism of citric acid in the body the end products are of alkaline nature.

Table 42 affords some idea of interstate shipments of citrus fruits from the important growing regions.

Oranges are shipped in refrigerator cars during the warmer months and during these periods it is advantageous to precool the fruit to 50°F.

TABLE 41.—HOW FRUITS RATE IN FOOD VALUE**

	Vitamins				Calcium	Iron	Fuel value per pound (calories)
	A	B	C	G			
Apples (fresh)	‡	‡	‡	‡	..	..	290
Apricots (fresh)	*	..	‡	..	..	..	255
Apricots (dried)	*	..	†	..	†	*	1,260
Bananas	†	‡	†	‡	..	..	445
Blackberries (or dewberries)	†	..	‡	..	..	†	285
Blueberries (or huckleberries)	‡	..	‡	..	..	†	310
Cantaloupe (see Muskmelon)							
Cherries	†	..	†	..	..	..	310
Cranberries	‡	..	†	..	..	..	240
Currants (fresh)	..	..	*	..	..	..	275
Currants (dried—see Raisins)							
Dates	†	‡	..	..	†	*	1,570
Figs (fresh)	‡	‡	‡	‡	†	..	395
Figs (cured)	‡	‡	..	‡	*	*	1,435
Gooseberries	..	..	*	..	..	..	215
Grapefruit	..	‡	*	‡	..	..	200
Grapes	‡	‡	‡	..	..	..	355
Guava	†	‡	*	‡	..	..	355
Lemons	..	..	*	..	..	..	200
Limes	..	..	*	..	†	..	240
Mangoes	*	‡	*	†	..	..	335
Muskmelon	†	‡	*	‡	..	..	125
Oranges	‡	†	*	‡	..	..	230
Papayas	*	‡	*	‡	..	..	195
Peaches (fresh)							
Yellow	*	..	†	..	..	..	230
White							
Peaches (dried)							
Yellow	*	..	*	..	†	*	1,325
White							
Pears (fresh)	..	‡	‡	†	..	..	315
Pears (dried)	..	†	..	†	†	†	1,460
Persimmons (Japanese)	..	..	‡	..	..	..	395
Pineapples	‡	†	†	‡	..	..	265
Plums (or fresh prunes)	..	..	‡	..	..	..	255
Prunes (dried)	*	†	‡	*	†	*	1,365
Raisins (including so-called dried currants)	‡	..	..	‡	†	*	1,480
Raspberries	..	..	*	..	..	†	Red 305
							Black 375
Strawberries	..	..	*	..	..	..	185
Tangerines	..	..	*	..	..	..	225
Watermelons	‡	‡	‡	‡	..	..	140

** Consumer's Guide, *U. S. Agric. Adjust. Admin.*, vol. 2, 18, July, 1935.
* Excellent
† Good
‡ Fair

or below. In view of the fact that the respiration rate of oranges doubles with each rise in temperature of 18°F., the need for cooling is essential.

of oranges cultivated in Florida and the Gulf states include Parson Brown, Hamlin, Seedlings, Pineapple, Valencia, and Leu Gim Gong. The Parson is an early-ripening variety, while the Pineapple is the leading midseason variety. The Valencias are the standard late variety. In the Rio Grande valley of Texas the Parson is known sometimes as the Texas Sweet. The so-called kid-glove types, having thin skins, include Dancy Tangerines, Satsumas, Mandarins, and King oranges. The Dancy tangerine is the principal member of this group which is shipped commercially.

The oranges used in the more heavily populated areas in this country [illegible]d in regions from 1,000 to 3,000 miles away, which requires considerable care on the part of the growers if their product is to reach the best markets in satisfactory condition. Oranges for distant shipment, therefore, are sometimes gathered when partly green and before they are fully ripe. Color and the characteristics used in determining the maturity of other types of fruit cannot be relied upon in the case of oranges, the most accurate method of judgment being to determine the ratio of total soluble solids, mainly sugars, to the acid content of the expressed juice of representative samples of fruit. Standards for shipment in some states have required definite ratios before the fruit could be shipped to prevent the marketing of unripe products. It has been found that arsenic sprays have a marked effect on these ratios.[1]

Careful handling is necessary in harvesting oranges in order to prevent injury or breaking the skin. Stems are cut as close to the fruit as possible. *Penicillium digitatum* and *Penicillium italicum*, two fungous organisms which cause serious rotting of oranges, gain a foothold easily through the injured skin. The latter may be transferred by direct contact with other infected fruit also. Diplodia and Phomopsis are the causative agents of stem-end rots which are important from the standpoint of economic losses. Precautions must be taken to avoid the damage caused by the above microorganisms as far as possible. These precautions should include sanitation in the groves and the removal of all infective material, careful mechanical handling of the fruit to avoid bruises and damages, removal of stem buttons in the packing house to facilitate inspection, the use of fungicidal compounds such as borax to inhibit mold growth, and the proper utilization of refrigerated storage.[2]

It has been found that solutions of borax are effective in checking the development of these microorganisms, and in a number of the larger packing houses the fruit is treated with such solutions. Dilute sodium carbonate treatment may also be used to lesson the incidence of mold rot caused by the Penicillia.

[1] *U. S. Dept. Agr. Tech. Bull.* 350, 1933.
[2] *U. S. Dept. Agr. Tech. Bull.* 488, 1935.

Certain varieties of oranges and grapefruit are green when ripe. Some are yellow or orange in color when the fruit is still immature and later revert to a greenish color. Valencias turn from green to yellow in the fall when the trees become dormant and the chlorophyll is dissipated, but when the new leaves come, the fruit becomes green again. Green-colored oranges are not generally acceptable however, even when they are mature, as buyers in distant states are not familiar with these facts. Since fruit which is not orange in color brings lower returns, and because there seems to be no relationship between the color, flavor, and maturity of citrus fruits, the use of a chemical treatment for coloring of the fruit has been allowed. Ethylene has been found efficacious in color production, as it hastens the disappearance of chlorophyll which causes the green, and allows the underlying orange pigments to be apparent.

Several factors are of the utmost importance in the coloring of citrus fruits by means of ethylene as it is carried out in the packing houses. These are control of temperature, air circulation, and concentration of the ethylene gas. Concentrations of ethylene as low as one part in 20,000 are said to be effective, using periods of time from 24 to 60 hours. Ethylene has no effect on sugar-acid ratios, but its use is not permitted except for mature fruits. Similar methods of treatment are sometimes used for lemons, grapefruit, Bartlett pears, and tomatoes.

In recent years from 80 to 90 per cent of the Navel orange crop from northern and central California, some 7,000 carloads, has been treated with ethylene. About 25 to 30 per cent of the Navel oranges from the southern part of California, about 25,000 carloads, are so treated.

The Valencia oranges are treated to a widely varying extent, depending on weather conditions and the time when the fruit matures. In the spring the oranges are highly colored, even though the fruit is immature, but with the approach of hot weather the stem and blossom ends turn pale and assume a greenish cast which varies in extent in different areas. The percentage of fruit treated varies in extent in different years from 10 to 25 per cent to as high as 75 per cent which was the case in 1933–1934.[1]

The coloring of fruit by means of dyes is at present only in the experimental stages in California.

Temperatures of 70 to 80°F. or above may be used for the citrus-coloring or sweating process, with high relative humidities sometimes 85 to 95 per cent, to prevent undue evaporation. During this treatment normal respiration of the fruit increases the carbon dioxide of the air in coloring rooms which are usually well filled with field boxes and may hold 30 or more tons of fruit. According to Addington,[2] if the concentration

[1] Personal communication from Food Research Division, U. S. Dept. Agr., Los Angeles, Calif.

[2] ADDINGTON, H. H., *Refrigerating Eng.*, **29**, 185, 1935.

of carbon dioxide in the air rises unduly, the action of ethylene is likely to be retarded or the fruit may be injured by other evolved gaseous metabolic products. Therefore forced ventilation and periodic removal of the air in the room may be necessary, followed by bringing the ethylene concentration again up to that found desirable. Opinions vary concerning the exact humidities and temperatures, but Addington states that 70°F. is the usual temperature for lemons, 75°F. for grapefruit, and between 70 and 80°F. for orange treatment. According to the same

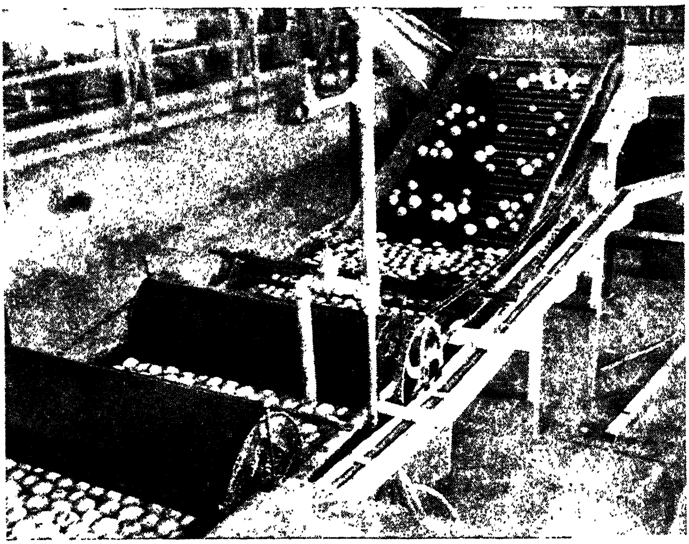


FIG. 19.—Cleaning citrus fruit. (*Food Industries.*)

author, the ethylene concentrations used for lemons is about 0.1 cu. ft. of gas for each 400 boxes of fruit or 1 cu. ft. per 20,000 cu. ft. of air space, while for oranges four times as much is used. Grapefruit are treated with concentrations of ethylene twice those cited for lemons. The various air conditions required usually necessitate humidification equipment as well as heating equipment.

According to Winston, acetylene may be used for the same purpose with citrus fruits, although it acts less rapidly. He found that there was less likelihood of scald and that fruit treated with it possessed better keeping qualities than that treated with ethylene.[1] He also reported that treatment by either gas impaired keeping quality somewhat.

As the temperatures used in the coloring process favor the development of stem rot and molds, oranges are now quite commonly washed in an 8 per cent borax solution at a temperature of about 110°F. for a

[1] WINSTON, J. R., *Citrus Ind.*, **16**, 3, 1935, and *U. S. Dept. Agr. Tech. Bull.* 488, 1935.

brief period, usually not over 5 minutes. Warming the fruit slightly tends to prevent the crystallization of borax on the orange skin and also raises the temperature somewhat in the direction needed in the subsequent coloring process, especially in cold weather. Much fruit which does not require

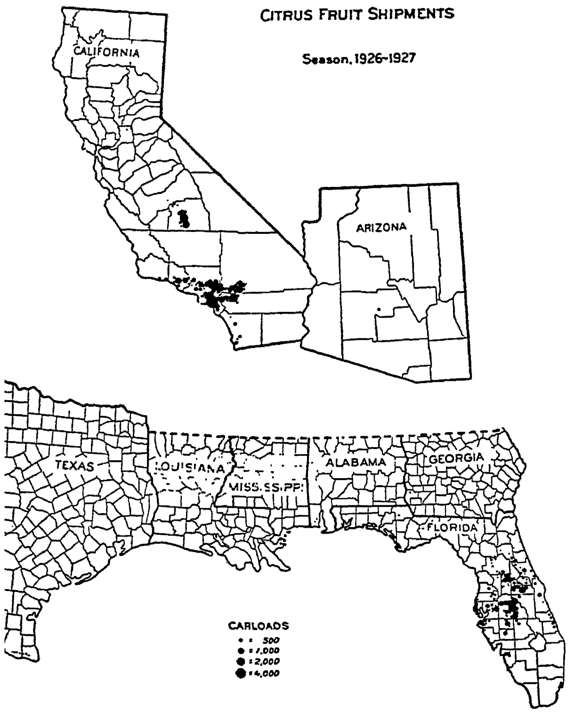


FIG. 20.—Each shipping point in California and Florida is shown by a dot, the size of the dot varying with the number of carloads shipped. There are about 20,000,000 citrus trees in California, mostly oranges and lemons, principally on the alluvial fans and piedmont slopes that fringe the valley from Los Angeles to Redlands, and on the fan formed by the Santa Ana and Santiago Rivers in northern Orange County, also on the slopes of the Santa Paula Valley in Ventura County. Another area is located on the slopes at the foot of the Sierras in Tulare County. On these foothill slopes the cool air drains off on frosty nights and the drainage of surplus irrigation water is also better than in the bottom lands. The Rio Grande delta of Texas has 5,000,000 citrus trees, mostly grapefruit, and 80 per cent under 5 years of age. The land is nearly level and the trees are irrigated. In Florida the 18,000,000 citrus trees, practically all oranges and grapefruit, are grown mostly on the sloping lands of the lake district in the central part of the State, and are not irrigated. (*From U. S. Dept. Agr.*)

special coloring treatment is treated with borax also, as this tends to prolong its storage life and quality in transit.

Dilute solutions of trisodium phosphate, soda ash, or other detergents which remove dirt, insects, or other foreign material are also frequently

employed to wash the fruit. After passing through a washing machine, the fruit is conveyed through a tank containing the borax solution, which is more effective if applied soon after the oranges are harvested, according to Winston.

A later polishing treatment of the outer skin may be used before grading and packing the fruit in crates. Paraffin, a fine spray of mineral oil, or carnauba-wax emulsions are sometimes applied. Rosin may be added to the washing water to accomplish the same purpose. A subsequent mechanical brushing or polishing by means of horsehair brushes is sometimes used to give the fruit a finished gloss. Such treatment not only improves the appearance of the fruit but also leaves a surface relatively impermeable to moisture which retards the loss of water from the fruit and thereby increases its keeping over a longer period of time. It is also believed to lower the entrance of mold infections and may retard respiration, thus tending to retard ripening also.

Oranges are graded according to size and quality, individually wrapped in paper which has sometimes been impregnated with mineral oil, and packed in cases or crates. The sizes are designated by the number of pieces of fruit which may be packed in a standard crate. Table 43 below indicates the numbers, orange sizes, and their limits according to standards of the United States Bureau of Agricultural Economics.[1]

TABLE 43.—SIZE GRADES OF ORANGE PACKS

Pack	Minimum diameter, in.	Maximum diameter, in.
96's	3 6/16	3 11/16
126's	3 3/16	3 8/16
150's	3	3 4/16
176's	2 14/16	3 2/16
200's	2 12/16	3
216's	2 10/16	2 14/16
250's	2 8/16	2 12/16
288's	2 6/16	2 10/16
324's	2 4/16	2 8/16

In order to keep the fruit as long as possible, it should be refrigerated to cut down normal metabolic changes. Temperatures of 40 to 45°F. are satisfactory for this purpose. Lower temperatures may be used but are not advisable over long periods because of changes which may occur in the oranges under such circumstances.

[1] *U. S. Dept. Agr., Bur. Agr. Econ.,* U. S. Standards for Citrus Fruits, Effective Sept. 15, 1934 (for Florida fruit).

GRAPEFRUIT

The grapefruit or pomelo has attained considerable importance in the citrus regions, especially in Florida. Its name is possibly due to the fact that the fruit sometimes grows in clusters, although not in the same general manner as grapes. The trees resemble the orange in some respects but tend to be larger and more round-topped, with shiny dark-green leaves. Although grown in this country for more than a hundred years, it has been a market crop for only about half of that time.

The grapefruit has an acid, sometimes even bitter, taste to which one must become accustomed. Once the taste is acquired, the fruit is held in high esteem. In the United States it has become a very popular breakfast fruit, being served usually after being cut in halves. It is also widely used in salads and as an appetizer before the luncheon and evening meals. More recently the juice and pulp have been canned in large quantities. This has overcome the inconvenience of the former method of utilization and has increased consumption.

Florida is the largest producer of grapefruit, with California, Texas, and Arizona next in order from the standpoint of production. Puerto Rico produces fruit of good quality, and large quantities of grapefruit are raised in the West Indies.

The more common varieties are the Hall, Walters, Duncan, Davis, and McCarthy Marsh. There are also some pink-fleshed varieties which are more frequently grown in the Rio Grande valley in Texas.

Grapefruit are handled in much the same manner as oranges. They may also be treated in order to bring about desired color changes in the mature fruit.

Because of their larger size, the units per box differ considerably from oranges, as may be noted in Table 44 showing United States standards for this fruit.

TABLE 44.—SIZE GRADES OF GRAPEFRUIT PACKS*

Pack	Minimum	Maximum
36's	5	5 9/16
46's	4 11/16	5 2/16
54's	4 6/16	4 13/16
64's	4 3/16	4 9/16
70's	3 15/16	4 5/16
80's	3 12/16	4 2/16
96's	3 9/16	3 15/16
126's	3 5/16	3 11/16

* *U. S. Dept. Agr., Bur. Agr. Econ.*

LEMONS

Lemons are an important fruit crop requiring a warm mild climate and are cultivated for commercial purposes particularly in southern California. As the lemon is a native of tropical and subtropical regions, the Mediterranean countries are especially favorable to the culture of this fruit. Many lemons are produced in Spain, Portugal, and Italy. Sicily is especially noted for its lemons. England receives a considerable part of its lemons from the Azores.

Lemons are cut from the trees while still green, but after they have attained practically full size, as the keeping qualities and flavor are said to be enhanced by ripening under controlled conditions. In general, lemons keep better than oranges and are not likely to be injured so easily. Their high acidity tends to retard fungous action, but they are subject to such attack. In this country lemons are usually individually wrapped in tissue paper and handled in much the same manner as oranges.

Certain by-products may be obtained from cull and surplus lemons, particularly citric acid, which is used in the carbonated beverage industry, and pectin, which has its main utilization in the jelly-making industry.

LIMES

The lime is an oval, green to yellow-colored fruit, usually ranging in diameter from 1 to 2½ in. It is more acid than the lemon and therefore is not suitable for eating purposes. It is a valuable source of tart flavor and is used in beverages and "ades" during the warmer seasons. Limes are also used for the manufacture of bottled lime juice which is a drink much esteemed, particularly by the English. It is also the source of essential oil. The fruit of the lime has long been recognized as an agency to combat scurvy, and contains vitamin C. Fresh limes are quite perishable and should be refrigerated if kept for any length of time.

Limes are grown on a commercial scale in Italy, Mexico, Jamaica, and Dominica. The domestic crop in the United States is grown almost exclusively in Florida, particularly in the Southern Keys which have a very warm climate. Owing to this fact, domestic limes are frequently known as Key limes. The Tahiti variety is the most common in Florida. In 1933, the United States produced 8,000 boxes valued at $24,000.

OTHER CITRUS FRUITS

Kumquats are very small-sized fruits closely related to other citrus fruits. They are rarely shipped commercially but are capable of use for jellies and similar products. Sometimes they are grown for ornamental purposes. Another citrus relative is the *calamondin,* a small very acid

fruit. The *citron* is a large yellow fruit which has attained limited consumption in its dried and candied form.

In addition to the citrus fruits already mentioned, there are several fruits which have been derived by crossing. The *citrange* was derived by crossing the trifoliate orange and the sweet orange. *Tangelos* have resulted from crossing tangerines and grapefruit, yet the resulting fruit more nearly resembles an orange. *Limequats* have resulted from the crossing of kumquats and limes by Swingle who has devoted much effort in this field.[1]

CITRUS BY-PRODUCTS

There are numerous citrus by-products which have become important commercially. Canned grapefruit and the canned juice of the three most widely used citrus fruits have become widely used in the last decade. Some of these same juices are frozen and are meeting with favor in refrigerated form. Dried powdered citrus juices have been made and marketed to a certain extent. Lemon oil and orange oil have been used for many years and more recently, since grapefruit have been canned extensively, grapefruit oil and grapefruit-seed oil have been produced in Florida.[2,3] Citrus pectin is now manufactured in large quantity for use in the jelly and jam industries. Citric acid is manufactured from cull fruit and the skins. Candied peel may also be made from the peel. Marmalades and jellies are produced from numerous citrus fruits, either alone or in combination.[4] Since the repeal of prohibition progress has been made in the utilization of citrus culls and wastes for the making of fermented beverages.[5]

STRAWBERRIES (*Fragaria virginiana*)

Strawberries have originated from two species which are apparently native to America, the wild strawberry of the Eastern areas, *F. virginiana*, and the wild beach strawberry of the Pacific coast *F. chiloensis*, according to Darrow and Waldo.[6] The latter also occurs in Chile and in the Hawaiian Islands. The modern varieties resulted from these earlier species which were hybridized in Europe from American plants. According to these authors, strawberries have been grown commercially since

[1] SWINGLE, W. T., T. R. ROBINSON, E. M. SAVAGE, *U. S. Dept. Agr. Circ.* 181, 1931.
[2] NELSON, E. K., H. H. MOTTERN, *Ind. Eng. Chem.*, **26**, 634, 1934.
[3] JAMIESON, G. S., W. F. BAUGHMAN, S. I. GERTLER, *Oil Fat Ind.*, **7**, 181, 1930.
[4] CHACE, E. M., *U. S. Dept. Agr. Circ.* 232, 1925.
[5] VON LOESEKE, H. W., *The Citrus Ind.*, **15**, 8, 1934.
[6] DARROW, G. M., and G. F. WALDO, Strawberry Varieties in the United States, *U. S. Dept. Agr. Farmers' Bull.* 1043, 1919, revised 1935.

1800 when this fruit was cultivated around the principal Eastern cities of that date, Boston, New York, Philadelphia, and Baltimore. About 100 years ago, strawberry cultivation extended to Rochester, New York, and sometime later it developed in southern New Jersey, Virginia, and the Delaware and Maryland peninsula. In the latter part of the past century Michigan, Illinois, Tennessee, Arkansas, Florida, and Louisiana extended this type of cultivation. More recently Alabama, North Carolina, Missouri, California, Oregon, and Washington have become extensive growing areas and strawberries can be obtained in the fresh state over most of the year.

The Wilson variety was one of the first which was widely grown, but in the past forty years many varieties have attained localized importance. Florida specializes in the Missionary which is also grown in the Pacific States. The Marshall is cultivated in Oregon. Klondike and Blakemore are Southern varieties. Aroma, Dunlap, and Progressive are grown extensively in the Middle West. Other prominent varieties include Howard 17, Corvallis, Nich Ohmer, and Ettersberg 121. About 30 varieties have attained extensive use dependent on the climate, soil requirements, and dormancy characteristics of the plants, as well as on the diseases prevalent in various areas.

Strawberries are grown for a number of purposes and for different markets. In some instances it is desirable to obtain very early fruit, in others the time of maturity is of less importance than the extension of the bearing period. Some fruit is grown exclusively for preserving and freezing purposes. Other types are grown for shipment over long distances. Appearance is sometimes the primary requisite, in other cases flavor or color may be more important. New York, Chicago, Boston, and Philadelphia are the largest market areas in the order cited. New York uses about 15,000,000 qt. of fresh strawberries a year.[1] Canning varieties most widely used in Washington and Oregon are Ettersberg 121, Corvallis, Redheart, and to a lesser extent Wilson, and Clark. Other varieties grown in the Middle West and farther North are Warfield, Dunlap, and Parsons. For these purposes a deep red unfading color and acid flavor combined with firm medium-sized berries are essential.

For preserving, a bright red nondarkening medium-sized berry with high flavor, such as the Blakemore, is preferred.

The freezing of strawberries is now carried out on a large scale using Corvallis, Marshall, Clark Seedling, Redheart, Ettersberg, and others in the Pacific states, according to Diehl and his coworkers.[2]

[1] Strowbridge, J. W., *U. S. Dept. Agr. Tech. Bull.* 180, 1930.

[2] Diehl, H. C., W. T. Pentzer, J. A. Berry, and C. E. Asbury, *Western Canner and Packer*, September, October, November, and December, 1935.

For the ice-cream industry, which uses tremendous quantities of strawberries, the Marshall variety having high flavor and deep-red color is a favorite along with the Klondike and a few others.

Strawberries are subject to fungous diseases such as gray mold, due to Botrytis, also to leaf spot, scorch, leaf blight, and mildew. There are several rots such as tan rot and leather rot, as well as strawberry yellows, a virus disease. Among their insect pests are the strawberry weevil and the red spider.

Many strawberries are grown for home and local consumption and never enter commercial channels. The greatest areas of production for market and manufacturing purposes are the Southern and Eastern states and the Pacific Northwest. Table 45 indicates the importance of the commercial crop.

TABLE 45.—PRODUCTION AND VALUE OF STRAWBERRIES IN THE UNITED STATES

Year	Production, 1,000 qt.	Value, $1,000
1919	176,932	36,004
1929	330,872	43,167
1931	270,864	37,376

Strawberries have a high water content and very low percentages of protein and fat. Their carbohydrate accounts for most of their total solids as shown in the average analysis by Chatfield and McLaughlin.

TABLE 46.—COMPOSITION OF STRAWBERRIES

	Per Cent
Refuse	4.0
Water	90.0
Protein	0.8
Fat	0.6
Carbohydrate	8.1
Ash	0.5
Acids (as citric)	1.09

The strawberry is an herbaceous perennial, small, usually less than 10 in. in height, which propagates itself by short runners. The leaves are three-parted, rather rough, with serrated edges; the flowers are white, mostly in clumps, and sterile. The fruits vary much in size and shape, from less than ½ in. to more than 1½ in. in diameter, made up of many small abortive seeds and the coalescence of the pulpy base, generally red in color and with a fine flavor. The fruit is very tender so that it requires both care and protection in handling and remains in good condition for

only a short time. The plant thrives best on a rather light moderately moist soil and is short-lived, the beds usually being replaced every two or three years.

Cultivation has resulted in an increase in the size of the plants and fruit, in better production, and extension of the bearing period, but in most cases with some impairment of its original flavor. The wild berry is peculiarly rich in flavor and odor of a most delicate kind, qualities poorly developed in large, pulpy fruit. The qualities which do remain are injured by the high temperature necessary for sterilization if strawberries are canned and the appearance is also altered so that their best qualities are evident only in the fresh state. Conservation with sugar in the form of a jam is a popular use for strawberries. They are also frozen, either with or without sugar, to a considerable extent.

For market purposes strawberries are carefully picked with stems attached and packed in quart and pint boxes immediately. These are packed in crates having 32 large boxes and spacers between each layer of boxes. Even with care in handling, soft or over-mature fruit, or that picked wet, is likely to show spoilage, especially in the bottom of the boxes. More rigid drawer-like chests are sometimes used in the West. High temperatures reduce the storage life of the fruit especially if it has been carelessly handled. Refrigeration lessens spoilage losses in transit and temperatures in freight cars should be lower than 45°F. for best results, according to Stevens.[1]

When picked for manufacturing purposes, the berries may be hulled in the field. In the factory they are thoroughly washed and rinsed with pure water, drained carefully, then sorted or graded. Many strawberries are packed in barrels with sugar, in a 2:1 or 3:1 proportion, the barrels rolled to mix the fruit and sugar, then placed in freezing rooms. As the time required for the berries to reach the temperature of the freezing room may take several days, the berries are sometimes precooled before packing in barrels to obviate spoilage. Usually such barrels are rolled each day to mix the fruit and resulting sirup. Precooling the fruit before shipment is helpful in maintaining such temperatures.

For freezing strawberries in smaller sized containers, such as airtight lacquered cans, the fruit, either whole or sliced, may be packed in sucrose sirup of 40 to 60 per cent concentration. Dry sugar is sometimes used in a 4:1 or 3:1 ratio with sliced fruit. The product should be stored at temperatures of 0°F. for optimum keeping qualities. Storage at 20°F. enables color changes to go on which are undesirable, according to Diehl and his colleagues, because enzymes are able to work even when the products are frozen.[2]

[1] Stevens, N. E., *U. S. Dept. Agr. Farmers' Bull.* 1458, 1930.

[2] Diehl, H. C., J. H. Dingle, and J. A. Berry, *Food Ind.*, **5**, 300, 1933.

PEARS

The pear tree (Pyrus) has characteristics similar to those of the apple, although its bark, foliage, and flowers are distinctive. The most common species is *Pyrus communis*, the common pear, which probably originated in Europe. There are others of Asiatic origin and some hybrids. The fruit is a pome having five carpels, with two seeds in each cavity. The common pear is characterized by its shape, flavor, and structural features, which include clusters of cells, of a woody nature distributed in the flesh.

Like the apple, the pear grows well in the temperate zone of both hemispheres. France, Germany, Belgium, and England are the major pear-growing countries of Europe. In the United States, certain localities in the states on the Pacific coast, the fruit belt about the Great Lakes, and the Atlantic-seaboard states are best suited for pear culture, although pears are grown in practically every state. The danger of spring frosts, which are likely to be destructive, limit the planting of pear orchards to areas where such frosts are minimized.

The pear has never attained so important a position as the apple in our agricultural system in spite of its pleasant flavor, owing, perhaps, to its susceptibility to disease and its inability to withstand storage conditions with uniform satisfaction.

TABLE 47.—PEARS: PRODUCTION BY LEADING STATES*
(1,000 bu.)

State	Average 1926–1930	1932
California....	8,955	9,917
Washington..	3,275	3,723
Oregon.......	2,523	2,808
New York....	1,670	1,745
Michigan.....	682	783
Pennsylvania.	482	384
Colorado.....	406	377
Total (United States).	22,921	22,050

* Yearbook of Agriculture, 1934.

During 1932–1933 the United States exported 59,000 tons of fresh pears and 30,000 tons of canned pears.

There are numerous varieties of pears. The Bartlett is possibly the best known. Clapp, Anjou, Seckel, Bosc, Kieffer, Sheldon, and Conice are others that attain usage in various sections.

The pear tree is subject to the depredations of insects, especially the codling moth and borers. Fungous and bacterial diseases are also encoun-

tered by pear growers. "Fire blight," a disease caused by bacteria, is a serious menace in some sections and is combated chiefly by eradicating diseased branches or trees.

Pears are usually harvested before reaching full maturity, *i.e.*, when they have attained full size but have not started to soften. If allowed to remain on the trees until completely ripened, the fruit has a tendency to become mushy or coarse in texture, and lacking in flavor, whereas that ripened in boxes in rooms maintained around 70°F. with good ventilation are fine-grained, juicy, and of superior flavor. Pears should be placed in cold storage (30 to 31°F.) if they are to be kept for some time. In this manner they may be kept satisfactorily for a number of weeks, although too extensive storage is followed by rapid deterioration.[1]

Many pears are now shipped from the Pacific Northwest to Eastern markets. Because of their need for careful handling in storage and transit, much attention has been given to such problems. Mallison and Powell have found that when Bartlett pears are picked at the proper stage of maturity, they can be shipped at temperatures of 41 to 43°F. for 10 to 12 days' transit and remain in good market condition after 2 months' storage at 32°F.[2]

The oxidase system in pears is highly developed and must be checked or destroyed in order to prevent discoloration after peeling. Pears may be dried in the sun or by rapid artificial dehydration under conditions of properly controlled temperature and humidity.

TABLE 48.—CHEMICAL COMPOSITION OF PEARS

	Per Cent
Water	82.7
Protein	0.7
Fat	0.4
Ash	0.39
Carbohydrates:	
Total and fiber	15.8
Fiber	1.4
Sugar as invert	8.9
Acid as citric	0.29
Refuse	17.0

The canning of pears is an important commercial industry in this country. In 1931 there were almost 4 million cases of pears canned, with a value of over 12 million dollars. Pears are also pickled to a small extent. Another use of pears is as one of the constituents of the canned "fruit salad" which has become a popular product in the past decade.

[1] MAGNESS, J. R., H. C. DIEHL, and F. W. ALLEN, Investigations on the Handling of Bartlett Pears from Pacific Coast Districts, *U. S. Dept. Agr. Tech. Bull.* 140, 1929.

[2] MALLISON, E. D., and C. L. POWELL, *U. S. Dept. Agr. Tech. Bull.* 434, 1934.

GRAPES (*Vitis*)

Grapes have been known to man for many centuries. Biblical traditions certify that the grape and its fermented products were appreciated in the Mediterranean regions which are still the locations of thousands of vineyards. Wild grapes were found in America by its early explorers, one group of which suggested the name "Vineland" for a part of North America. This fruit thrives in the middle belt of the north temperate zone, especially in Europe and North America. France, Italy, Rumania, parts of Spain, Germany, Russia, Switzerland, Austria, and numerous other European countries raise enormous quantities of grapes for the manufacture of wine, and in Spain and Greece especially they are dried in large quantities to produce raisins. Grapes are also grown abundantly in Asia Minor, in parts of Africa and in Australia and South America.

TABLE 49.—1932 GRAPE PRODUCTION
(Tons)

California	1,926,000
Michigan	71,220
New York	67,971
Ohio	30,000
Pennsylvania	22,977

California, where the ideal conditions of climate and soil for grapes prevail, is by far the largest producing state. In 1932 this state produced 1,926,000 tons of grapes out of a total United States production of 2,203,000 tons. Of the California production, 388,000 tons, or about 20 per cent, were wine varieties, which bid fair to increase somewhat with the cessation of prohibition. New York and Michigan are the next largest grape producers from the standpoint of volume.

Three principal types of grapes are grown in this country: the Vinifera (*Vitis vinifera*), the American euvitis, and the muscadine. Vinifera grapes, introduced from Europe, are raised chiefly west of the Rocky Mountains, but almost exclusively in California. In the region bordering the Great Lakes and north of the Ohio River the American euvitis is the principal grape. The muscadine type is grown along the Atlantic coastal plain and in the Gulf region and the lower Mississippi valley.

The three types are subdivided into numerous varieties, of which the following are most important. Certain of their characteristics are included.

Varieties. Vinifera Type. The Alicante Bouschet—A black grape, very productive, ships well, has a dark red juice and is used almost entirely for juice.

Black Hamburg—Black, very productive, juicy flesh, aromatic flavor, an all-round grape, one of the best known varieties and much used as a table fruit.

Cornichon—Black, very productive, large berries, fruity and pleasant flavor, an excellent market grape, ships well, usually attractive.

Hunisa—Black, large berries, excellent for shipping or storage, an especially good eating grape.

Zinfandel—Black, very productive, juicy, medium-sized berry, the most widely grown red-juice grape, good eating.

Muscat of Alexandria—White, large berry, thick tough skin, attractive, pleasing flavor, important raisin grape.

Sultana—White, small berry, sweet juice, seedless, thin tough skin, a raisin grape, but also makes a good juice.

Thompson (Sultanina)—White, unusually productive, berries a little above medium in size, tough skin, sweet in flavor, seedless, an excellent grape for the table or for raisins, a good shipper.

American Euvitis Type. Concord—Blue-black, medium to large round berry, juicy, not especially pleasing in flavor except when perfectly ripe, much used for grape juice, most widely grown grape in this country.

Worden—Black, large berry, juicy, sweet at skin and tart at center, much like the Concord, but generally of better quality.

Catawba—Red, medium sized berry, juicy, fine-grained, very good flavor, "excellent all-purpose grape," ripens late, keeps and ships well.

Delaware—Red, small to medium berry, thin skin, juicy, tender, sweet, fine quality, ranks next to Concord grape in popularity for the garden and vineyard.

Niagara—White, light-green to yellowish green, rather large berry, thin skin, juicy, fine-grained, fair quality, good all-purpose grape.

Muscadine Type. Scuppernong—Productive, green to reddish brown, medium-thick skin, good quality, more widely grown than any other of the muscadine varieties, used for home purpose and juice.[1]

The most favorable soil for grapes is one which is well-drained, calcareous, preferably underlain by porous subsoil, and of fair fertility. Grapes can be grown on soils varying from sandy loam to heavy clay. Open subsoils are desirable to allow the escape of surplus water and enable the roots easy penetration. Overrich soils tend to produce rank growth of vines with generally reduced yields and fruit of medium quality. The vines, which may bear for many years, are propagated by rooting "cuttings" or "slips" from mature plants. The culture of grapes varies markedly with the variety and locality in which they are grown. The

[1] For more complete description of varieties see *U. S. Dept. Agr. Farmers' Bull.* 1689, 1932.

pruning of the vines is of great importance because of its effect on the yield.

Warm dry weather is essential for the ripening of the grapes, as both the fruit and the blossoms are sensitive to frost. The roots are capable of maintaining the plant in very dry regions because they extend to great depths. An example of this is the San Joaquin valley in California, where irrigation is needed for other plants, although grapes are grown extensively. Fresno, in this region, is probably the largest center of the raisin industry in the world.

The chemical composition of grapes is given in Table 50 as determined by Chatfield and McLaughlin.[1]

TABLE 50.—CHEMICAL COMPOSITION OF GRAPES*

Content	American type, per cent	European type, per cent
Water	81.9	81.6
Protein	1.4	0.8
Fat	1.4	0.4
Ash	0.45	0.46
Carbohydrates:		
Total plus fiber	14.9	16.7
Fiber	0.5	0.5
Sugar as invert	11.5	14.9
Acid, as malic	1.21	0.47
Refuse	22.0	3.0
Fuel value: per 100 gm.	77.8 Cal.	73.6 Cal.

* For an extensive discussion of changes in chemical composition of grapes during ripening, see *Univ. Calif. Pub. Agric. Sci.*, **3**, No. 6, 1918, by Bioletti, Cruess, and Davi.

The occurrence of rain during the period of maturation is dangerous, as it favors the growth of fungi which under such circumstances find grapes an ideal substrate.

The handling of grapes at harvest time is largely dependent upon their use. Those selected for table grapes receive the greatest care. For the markets many hundreds of miles away, separate bunches of grapes may be wrapped in tissue or wax paper, sometimes packed in small fancy baskets for the best retail trade, or carefully packed in cotton wool, but more often they are packed in wooden crates. Preservation for a limited time may be accomplished by packing the grapes with sawdust in boxes, barrels, or special containers. Malaga grapes, once imported in large quantities, are often packed in kegs with ground cork. Regardless of the type of container, fresh grapes should be kept cool and dry and handled with care. Especial care to insure minimum spoilage is taken in the trainload shipments of grapes from California to Eastern markets.

[1] *U S. Dept. Agr. Circ.* 50, 1931.

The handling of grapes to be used for raisins is somewhat less careful, although here also the occurrence of extreme moisture may be disastrous. Much less care is taken in the harvesting of wine grapes.

Table 51.—World Grape-wine Production, 1932

	Gallons of Wine
France	1,258,351,000
Italy	1,220,408,000
Spain	528,153,000
Portugal	158,502,000
Rumania	158,502,000
Greece	78,601,000
Argentina	66,043,000
Australia	16,428,000
United States	34,000

According to Carrick[1] a minimum storage temperature of 28.5 to 29°F. is safe for Emperor and Flame Tokay varieties of grapes, but for Malaga and other succulent grapes the air temperature should never fall below 30°F. A relative humidity of 85 to 90 per cent is necessary for the Emperor variety under the above conditions of temperature to prevent wilting over considerable periods.

Besides having an important use as fresh fruit, the grape is the source of the entire raisin industry and the basis of the wine industry. In addition grapes are used as a raw material for grape juice which is produced in large quantities, particularly in the Great Lakes region. They are also used as the basic stock for many jams and jellies. The principal source of tartaric acid and tartrates is the grape, although they are by-products of the wine industry, and obtained from the "lees." Vinegar may also be obtained by permitting an aerobic bacterial fermentation of wine, which in turn is the result of a yeast fermentation. Stock food, fertilizer, tannin, and grape oil are also by-products of grapes.

PEACHES (*Prunus Persica*)

Peaches are among our most delectable fruits and deserve even wider usage and consumption than they have attained. They have been held in high esteem since their introduction, attributed to the early Spanish settlers in Florida. During the centuries the peach has migrated extensively and may be found over practically the entire United States. As it is susceptible to extreme cold, the large commercial orchards are generally confined to the regions with fairly moderate climates. California and Georgia are by far the outstanding peach growing states, although there are numerous others where the raising of peaches is an important agricultural industry.

[1] Carrick, D. B., Some cold-storage and freezing studies on the fruit of the Vinifera grape, *Memoir* 131, Cornell Univ. Exp. Sta., 1930.

The Great Lakes regions, where the tempering action of these large bodies of water tends to minimize the losses owing to early bloom, spring-frost injury, and winter killing, also produce large peach crops, as do the Carolinas and the Chesapeake Bay regions.

TABLE 52.—PRODUCTION AND FARM VALUE OF PEACHES, UNITED STATES*

Year	Production, 1,000 bu.	Value, $1,000
1929	45,026†	60,982
1930	53,864†	43,825
1931	77,743	41,377
1935	56,575	44,026

* Commerce Yearbook, vol. 1, United States, 1936.
† Includes some quantities not harvested on account of market conditions. Values are for quantities harvested.

In Europe the temperature is somewhat too low for successful peach growing except in Spain, southern France, and Italy. This fruit is well adapted to the climate of certain parts of Argentina, Australia, Chile, New Zealand and South Africa. These countries export some fruit to Europe.

The peach is a relatively perishable fruit, and unfortunately the very finest peaches are often those which are most delicate and least capable of extended shipment and storage. Large quantities of peaches are canned, and on the West Coast dehydration is used to preserve thousands of tons each year. Quick-freezing is also making peaches available at any time.

TABLE 53.—PEACH PRODUCTION IN LEADING STATES*
(1,000 bu.)

State	Average, 1926–1930	1932	1935
California.......	23,059	22,794	17,876
Clingstone...	14,867	14,168	11,709
Freestone.....	8,192	8,626	6,167
Georgia........	6,909	1,170	5,628
New Jersey.....	2,056	1,776	800
North Carolina.	1,846	1,645	2,205
New York.....	1,720	1,663	793
Pennsylvania...	1,513	1,676	1,675
United States...	56,575	42,443	52,380

* Yearbook of Agriculture, 1936.

There are many varieties, including the J. H. Hale, Elberta, Greensboro, Belle, Crosby, St. John, Mayflower, Ideal, Paragon, Tuskena, Crawford, Rochester, Foster, Sellers Cling, and Massasoit.

There are two general classes of peaches, clingstones and freestones. This arbitrary separation depends on whether the pulp adheres to the pit or may be separated easily and freely. The fruit varies in color from almost white to deep yellow and red.

TABLE 54.—CHEMICAL COMPOSITION OF PEACHES*

Content	Per Cent
Refuse (pits and stems)	12.0
Water	86.9
Protein	0.5
Fat	0.1
Carbohydrate (total)	12.0
Ash	0.47
Acid (as malic)	0.64

* CHATFIELD, C., and L. I. MCLAUGHLIN, Proximate Composition of Fresh Fruits, *U. S. Dept. Agr. Circ.* 50, 1931.

Among the diseases which cause trouble are scale, leaf curl, curculio, and brown rot.[1] The most serious insect pest is the peach borer.

Peaches are widely used as a fresh fruit and are also canned and dehydrated in large quantities. The equivalent of over 6 per cent of our peach crop is exported each year in these various forms, although canned peaches make up the great bulk of our exports of this crop as shown in Table 55.

TABLE 55.—PEACHES: TOTAL PRODUCTION OF PEACHES AND PEACH PRODUCTS AND EXPORTS OF THE UNITED STATES*

Year	Production, 1,000 bu.	Domestic exports				
		Fresh, 1,000 lb.	Dried, 1,000 lb.	Canned, 1,000 lb.	Total in terms of fresh, 1,000 bu.	Production, per cent
1924	51,146	16,172	4,668	57,390	3,240	6.3
1929	44,434	19,973	3,847	74,470	3,941	8.9
1932	42,443	3,298	7,649	74,999	4,032	9.5
1933	44,692	3,371	7,569	81,464	4,224	9.5

* Yearbook of Agriculture, 1935.

The fresh fruit is marketed largely in baskets. These containers may have a capacity of 1 bu., but for some types of trade smaller flat baskets are used in which case the baskets are packed in crates for shipment.

If peaches are to be shipped long distances, it is necessary to use low temperatures in transit. In some instances they are individually wrapped in paper.

[1] ROBERTS, J. W., and J. C. DUNEGAN, *U. S. Dept. Agr. Farmers' Bull.* 1527, 1927.

BANANAS

The value of the banana as a food for man has been known for many centuries, as it was recorded that in 327 B.C. this fruit was found by the army of Alexander in the valley of the Indus. The Arabs are said to have introduced this fruit into the Holy Land and Egypt in the seventh century, and eventually carried it across Africa. The Portuguese are credited with carrying banana plants from the Guinea coast to the Canary Islands in the latter part of the fifteenth century, and a Spanish priest, Father Tomas de Berlanga, carried some of the roots from the latter place to Santo Domingo in 1516. In his later migrations he carried the plant to Panama, thereby establishing it in tropical America where it has since flourished and provided an important source of food.

The development in commerce of the banana trade is a romance in itself. Bananas are believed to have been shipped from Cuba to New York in the early part of the nineteenth century. The first regular importations were shortly after the Civil War and came from the present Panama Canal Zone. A Cape Cod sea captain landed the first full cargo of bananas and tropical fruits from Jamaica in Boston in the spring of 1872. A few years later regular shipments were started from Costa Rica to New Orleans and later to New York.

In 1885 a group of Boston business men formed a company which has since extended its operations and become an organization of great importance, not only through the transportation of bananas, but by the establishment of extensive plantations, growing bananas, sugar, cacao, coconuts, and other tropical products, which are located in Central America, Mexico, the West Indies, and elsewhere in the Caribbean. These products are shipped not only to North America but also to Europe, and the extent to which such operations have grown may be appreciated by citing the fact that the fleet of vessels used by this one organization has over 100 steamships to transport its products and supplies. Research laboratories are maintained where experiments are carried on concerning plant diseases, soil and fertilizer investigations, plant breeding and the manifold problems which confront an industry of this nature. Hospitals have been established which are available for over 150,000 people who are connected with this one company. Other organizations are interested in the production and sale of tropical fruit, but it is significant that such a great organization should be developed as a result of the efforts of a small group which started originally to handle one food which was at the time almost unknown. Since that time the banana has come to be one of our most popular foods, is known all over the country and may be secured at all seasons of the year in spite of the fact that it is a fruit of highly perishable nature.

The most important species of banana are *Musa sapientum*, found in the West Indies and Caribbean countries, *Musa Cavendishii* (dwarf variety) which is found in the Canary Islands, Africa, in portions of Asia, and in the islands of the Pacific and Indian Oceans, *Musa paradisaica* (supposedly deriving its name from the legend that the banana was present in the Garden of Eden). The last named is also known as the plantain, grows in most tropical regions luxuriantly and is a staple food of the natives, but unlike the other species is usually cooked before eating.

The outstanding commercial variety of *Musa sapientum* is the Gros Michel, which is the ordinary banana of commerce and the principal one grown in the American tropics.

The cultivated banana does not usually produce fertile seeds so the planting is done with "bits," *i.e.*, pieces of root stock or rhizome. These are placed in holes, about a foot deep and 15 to 25 ft. apart in areas from which the tropical undergrowth has been cleared. After the planting, the larger trees in the area are felled and the remains of the trees allowed to remain as a mulch, or in some cases trunks and larger branches are burned. At regular intervals thereafter the plot is cleaned by cutting down the rapidly growing vegetation and by removing the branches of the forest trees which have not decayed in the meantime.

In a period of from 12 to 15 months the first fruit is harvested. This is accomplished by nicking the trunk of the tree a few feet below the bunch so that it bends and eventually lowers the fruit to the ground where "backers" or men who carry the fruit on their backs let the bunch settle on their shoulders very carefully so that it will not be damaged. The "tree" is immediately cut down and allowed to decompose, which occurs in the tropics with a rapidity that is matched only by the growth of the plant. The trees which are in reality gigantic bundles of leaf stems and are not woody, reach a height of 20 ft. or more in a little over a year, and cutting them down does not stop the growth of the banana plant itself as the true stalk of the plant develops underground in a manner similar to that of the rhizome of the fern, and new buds are constantly being formed. From this underground growth there in a short time will be produced a number of stalks similar to that cut down, so many in fact that usually only a few are left in order to produce satisfactory fruit, and the others cut away. Thus in an old plantation the regular alignment first used in planting the bits disappears after a few seasons and instead there is an irregular dispersion of plants which have occurred as a result of the natural development of stalks from the rhizomes.

After the bunches or "stems" have been cut, they are rushed to the varied means of transportation that are available to get them to the boats which are designed especially to carry the fruit shipments to

the United States or Europe. They may be carried out to the railway line to the coast on pack animals, on the back of human carriers, on tram cars drawn by animals, or on narrow-gauge railways. Speed and care are the essentials, together with the use of refrigeration in order to keep the fruit in optimum condition until it reaches the consumer.

Every effort is taken to prevent mechanical bruising of the fruit. Conveyors especially designed to prevent damage are used to load the bananas on the boats. The holds of the fruit-carrying vessels are ventilated and refrigerated in order to maintain the temperature as near 57°F. as possible and at the same time to prevent the accumulation of carbon dioxide which results from the metabolism of the bananas due to natural respiratory processes of the fruit. The cooled fresh air obtained by passing the air over refrigerated brine coils is circulated through the storage room in which the fruit is securely held by racks in order to prevent bruising and injury in transit. The vessels are usually insulated in order that fuel costs may be conserved, and peculiar as it may seem, they are also equipped with heating systems which may be necessary at times to protect the fruit from cold because in the winter the vessels often experience freezing weather and bananas are susceptible to damage caused by temperatures lower than 50°F.

When bananas reach the port of destination, they are unloaded with equal care and immediately started on their sometimes extensive travels to their final market. Trains and insulated trucks are used, probably with more attention paid to the maintenance of proper conditions of temperature and ventilation than in the case of most other food products. On the speedy banana trains, which sometimes travel many hundred miles, agents accompany the shipments, keep a record of temperatures in each car at short intervals, and are responsible for the maintenance of conditions which will ensure the proper arrival of the fruit. Many of our other food industries could learn valuable lessons from the example set by those who are concerned with the handling of this fruit.

Recently the ultimate unit for bananas has come to be the "box" which contains a number of hands approximately the same as a bunch. Packing carefully in straw or paper enables handling with less damage, and also presents display advantages. Such boxes have recently been equipped with glass covers and electric lights which under proper control make not only neat display cabinets but at the same time maintain optimum temperature conditions for the fruit in the retail market.

The bananas are green and immature when cut from the plant, green when shipped, but must be mature and yellow to be acceptable to the retail trade. If yellow when received in this country, they must be disposed of immediately as the fruit is perishable since its ripening processes are rapid and therefore it cannot be kept indefinitely. Thus the ripening

is a matter of paramount importance. If the banana is to be used for food purposes, it is never allowed to ripen on the plant. Tree-ripened fruit is insipid and has lost its characteristic flavor and pleasing quality.[1]

In the ripening process the green color of the peel changes to yellow, in spite of the fact that the content of xanthophylls and carotin, which give rise to the yellow pigment, is constant in the green and ripe fruit. This color is masked in the green fruit by the presence of chlorophyll which breaks down during the ripening processes and enables the yellow pigments to become apparent, according to von Loesecke[2]. The process requires a number of days, usually from 4 to 9, depending on the stage of the fruit when the process starts. The temperature is important as lower temperatures tend to retard the rate of ripening. The usual temperatures are between 60 and 62°F. Regulated temperature, ventilation, and humidity are essential for proper control of ripening, as the problem is intimately concerned with the normal metabolic processes and the gases which are produced by the fruit. In some instances experiments have been conducted to assist in the ripening of the fruit by the use of chemical agents, particularly gases such as ethylene. The use of ethylene is of particular value in ripening fruit which is "dormant," a term given fruit which for some unknown reason may not otherwise reach the normal stages of maturity. In normal fruit it does not appear to accelerate the process of ripening to any extent.

The food value of the banana is not fully appreciated by many inhabitants of the temperate zone, in comparison to those living in the tropics, where it constitutes in many cases the chief carbohydrate in the diet of enormous numbers of people.[1] Its food value may well be compared with the potato which attains such wide usage in this country. The following composition of these two great sources of food is given by Atwater and Bryant.

Content	Potato, per cent	Banana, per cent
Water	78.3	75.3
Protein	2.2	1.3
Fat	0.1	0.6
Total carbohydrate, including fiber	18.0	22.0
Ash	1.0	0.8
Calories per pound	385.0	460.0

[1] PRESCOTT, S. C., The Banana, A Food of Exceptional Value, *Sci. Mon.*, January, 1918.

[2] VON LOESECKE, H., The Banana, A Challenge to Chemical Investigation, *J. Chem. Ed.*, vol. 7, 1537, 1930.

The preceding figures show that the edible portion of the banana has a chemical composition which approximates that of the potato to a marked degree but exceeds the potato in fuel or calorific value. It is particularly important as a source of carbohydrate and is also a good source of mineral salts and vitamins.[1] It contains vitamins A, B, and C (Eddy).

A process for the manufacture of banana powder has been developed which sprays the fresh crushed pulp of ripe bananas in an atmosphere of low pressure under controlled temperature which is said to preserve the vitamin content of the fruit and also retain the natural enzymes of the untreated product.

CRANBERRIES (*Vaccinium*)

There are three types of cranberries grown in this country, but only one variety, *Vaccinium macrocarpon*, is cultivated extensively. The plant is indigenous to North America and grows wild from North Carolina to the southern part of Canada. It is an inhabitant of peat swamps which are acidic in character, and occurs commonly in New England, New Jersey, and Wisconsin. For best results under cultivation, the soil should be drained to a depth of 18 in. below the surface, which is said to be helpful in reducing the growth of weeds and at the same time produce favorable yields and facilitate harvesting. In many cranberry bogs the areas are flooded to prevent injury to the plants during cold weather, and this practice may also be resorted to during periods of frost before harvesting. The same practice is said to protect the plants against destructive insects. Sand is also used in some cranberry regions to aid in the control of weeds, frosts, and drought. High summer temperatures encourage losses due to disease and loss of fruit during harvesting. If the weather is too cool the blossoming is retarded.

Vaccinium oxycoccus is known as speckled, moss, gray, or small cranberry. It grows in swamp peat along the Atlantic coast to the Carolinas, and in Wisconsin, Michigan, Washington, and Oregon. It is also an inhabitant of Northern Europe and Asia.

Vaccinium vitisidaea is known under various names including the following: European cranberry, rock cranberry; in Great Britain as cowberry and foxberry; and in Newfoundland as the partridge berry. This plant grows in rocky places and on high land in contrast to *V. macrocarpon.*

The plant is a low-growing evergreen vine with a dark-red fruit, somewhat elongated. There is some resemblance to a cherry in its external appearance. The vines trail above the moss, sometimes for several feet, with short vertical stems at close intervals. The fruit is fleshy and firm, usually matures late in the fall, and is extremely acid, sufficiently so that cranberries are rarely eaten in the raw state.

[1] The Story of the Banana, United Fruit Co., Boston, Mass.

The cranberry was first subjected to cultivation about 1824, but methods of culture have been more widely used and improved in recent decades. The peculiar soil conditions needed are such that the cultivation of this crop is limited. For commercial production it requires land which has been both ditched and diked in order that it may be drained or flooded. A reserve water supply is necessary for this latter purpose. Three or four years are necessary for a commercial crop after the cuttings are planted to start new beds, but after the bogs start to produce they may yield for a long time if properly attended.[1]

The berries may be hand-picked or collected by means of rakes, which are a sort of coarse comb which strips the berries from the vines. There are also some more highly mechanized pickers, which have not yet attained wide usage. The berries are separated from the combings or rakings by running them through a fanning mill which blows out the leaves and other extraneous matter. The fruit may be separated from the standpoint of maturity by dropping it on boards as the fully mature berries have less tendency to bounce and thus may be segregated in compartments close to the board while the others are collected at a greater distance from the board.

Cranberries are generally packed in crates or barrels and may go directly to market or be placed in cold storage. Storage temperatures between 40 and 50°F. are advocated, with the lower temperature during the later part of storage. The market for this fruit is best during the Thanksgiving and Christmas holidays, with which this fruit is traditionally connected. Canned cranberries and cranberry jelly have become quite popular and are used during the entire year. New bottled cranberry juice drinks have also taken up a part of the crop.

The cranberry is quite different from most fruits in having a high content of benzoic acid which renders it markedly resistant to rot. Mold infections which may occur are prevented by submerging the berries in water, a practice which has been known as far back as Indian times. Benzoic acid is not the only acid present, however, as about 80 per cent of the acid present is citric (approximately 20 per cent malic and only about 0.07 per cent benzoic acid).[2] Iodine is said to be present in the ash of cranberries in rather high quantities in comparison with other fruits.

Sugar concentrations are usually higher in the mature berries, and may vary from 2.5 to 5.6 per cent. The acid varies from 1.9 to 2.7 per cent. The total carbohydrates are approximately 11 per cent and the protein content is usually less than 0.5 per cent.[3]

[1] *U. S. Dept. Agr. Farmers' Bull.* 1400 and 1402, 1924.

[2] NELSON, E. K., *J. Am. Chem. Soc.*, **49**, 1300, 1927.

[3] CHATFIELD and McLAUGHLIN, *U. S. Dept. Agr. Circ.* 50, 1931.

The first record of cranberry preserving is contained in a letter written by Wm. Underwood, the pioneer American canner, to Capt. Stanwood Stanwood of the ship "Augusta," dated Jan. 10, 1828. The following quotation is taken from that letter.

> The cranberries in the bottles are preserved without sugar. I name this because should any person buy them for sweetmeats, they would be disappointed. They are to be used precisely as if purchased fresh from the market, and will keep any length of time before the cork is drawn. Any English people will understand them and should you fall in with any Men-of-War they will be very agreeable for Ship Stores for cabin use, or for any American families who wish for cranberry sauce.

Massachusetts produces approximately 70 per cent of the total commercial cranberry crop of the United States, which in 1929 had a value of over $7,000,000.[1] Greater crops were produced in the three succeeding years but the values have declined owing to economic conditions which are general throughout the food industries. Table 56 cites the relative importance of other producing states.

TABLE 56.—CRANBERRIES: PRODUCTION BY STATES
(Barrels)

State	1926–1930	1932
Massachusetts.......	381,000	395,000
New Jersey..........	131,400	80,000
Wisconsin...........	47,200	80,000
Washington.........	14,816	7,536
Oregon..............	5,560	2,300
Total United States	579,000	564,836

Cranberries are used for a number of popular food products other than cranberry sauce and cranberry jelly. Cranberry juice is bottled and sold as a beverage under the name of cranberry cocktail. Dehydrated cranberries have been produced for the bakery and pie-filling trade for some time and are packed for domestic use in cans. More recently a dehydrated cranberry pulp has been developed. This product is derived from pulp which has been separated from skins and seeds previous to being dehydrated. The actual drying process is accomplished in a few seconds and makes a product capable of use in punches, sherbets, and ice cream for flavoring purposes as well as for bakery products.[2]

[1] *Mass. Agr. Exp. Sta. Bull.* 265, 1930.
[2] FAWCETT, W., *Canning Age*, **17**, 235, 1936.

CHAPTER VII

SUGARS AND SIRUPS

SUGAR

The sugar industries of the United States constitute an important part of the food industries. In 1931 the products of the combined sugar industries, namely, beet sugar, cane sugar, and cane-sugar refining were valued at over 494 million dollars and gave employment to over 20,000 people, exclusive of those who raised, harvested, or transported the materials.

In its earlier days the cane-sugar industry was largely localized in Louisiana, where it was first put on a commercial basis in about 1794. The greatest crop ever produced in that state was in 1908, since which time there has been an irregular decline in production, owing in part to the deterioration of the Purple and Striped canes grown in that region for a long time. These are being restored somewhat by an imported variety from Java. Florida is the only other state where cane-sugar manufacture is carried on and this is due to a development of sugar production in the Everglades. The number of factories has decreased markedly in Louisiana, from 1,100 to less than 100 in 70 years, but those remaining are generally of much greater capacity.

Beet sugar in the United States is of more recent origin, 1879 being the approximate date of earliest successful operation, but it is now our most important source of home-grown sugar. For some years past the annual production of beet sugar has been over a million tons per year in this country. Colorado is the largest producing state, raising about 25 per cent of the crop, with California, Michigan, Utah, Idaho, Nebraska, and Montana following in that order.

In spite of the large quantities of sugar produced within our boundaries, it is necessary to import a large part of our supply from the tropics, notably from Cuba, Hawaii, Puerto Rico, the Philippines, and from the Virgin Islands.

The refining of imported sugar has been carried out on our Atlantic seaboard since Colonial times, but it has increased notably since the Civil War period. The total volume of refining of all imports in the years immediately after the war could be done in one of the present huge refineries, such as are located in New York, Boston, Philadelphia, New Orleans, San Francisco, and other coast cities. In 1931 the imports amounted to approximately 3 million tons of sugar, much of which is refined in these seacoast refineries.

TABLE 57.—INTERNATIONAL TRADE IN SUGAR*

Country	Average 1925–1929		1931		1932		1933	
	Exports, short tons	Imports, short tons	Exports, short tons	Imports, short tons	Exports, short tons	Imports, short tons	Exports, short tons	Imports, short tons
Principal exporting countries:								
Cuba	5,032,658	525	3,002,821	20	2,890,028	15	....	....
Netherlands Indies	2,380,762	3,634	1,739,182	2,985	1,668,464	2,526	1,283,018	55
Czechoslovakia	792,566	628	498,864	235	434,603	20	224,100	9
Philippine Islands	612,260	2,398	829,957	1,601	1,120,563	777	1,188,999	....
Dominican Republic	353,915	196	353,239	4	484,731	4	325,955	4
Peru	332,668	106	363,990	200	358,393	208	404,089	....
Poland	253,202	2,291	379,977	8,224	204,442	8,286	125,543	30
Mauritius	242,199	3	197,100	137	218,129	6	....	....
Australia	179,533	911	305,667	6	245,073	9,335	....	....
Germany	174,357	92,758	390,677	14,411	89,606	27,507	16,793	17,424
Belgium	152,164	77,890	57,802	54,984	81,679	82,398	150,504	124,358
British Guiana	113,607	447	133,668	52	153,527	66	142,333	50
U. S. S. R.	105,024	57,858	352,503	78	83,908	45,753	42,315	7,654
Principal importing countries:								
United States	167,360	4,428,566	52,577	3,176,259	49,004	2,971,271	50,496	2,874,127
United Kingdom	105,263	2,135,293	119,068	2,048,880	341,467	2,662,671	380,024	2,295,976
British India	40,084	904,568	38,084	698,310	33,878	469,360	41,447	347,042
China	2,072	823,225	220	716,628	145	389,726	193	283,528
Canada	89,914	524,446	8,771	475,765	6,224	434,178	10,183	395,735
France	251,691	460,753	297,863	372,806	312,095	451,432	299,731	437,030
Japan	204,103	414,134	176,146	218,611	97,543	44,400	151,995	146,178
Netherlands	284,204	316,951	36,366	125,990	30,506	159,627	56,469	117,090

* Yearbook of Agriculture, 1935.

TABLE 58.—SUGAR PRODUCTION IN THE UNITED STATES, HAWAII, PUERTO RICO, AND PHILIPPINE ISLANDS*

Year beginning July	Total cane and beet sugar, refined, short tons	Beet, (chiefly) refined), short tons	Cane (chiefly raw)				
			Continental United States, short tons	Puerto Rico, short tons	Hawaii, short tons	Philippine Islands, short tons	Total, short tons
1909–1910	1,791,108	512,469	331,726	346,786	517,090	168,254	1,363,856
1914–1915	2,282,021	722,054	246,620	346,490	646,000	421,192	1,660,302
1919–1920	2,259,514	726,451	122,125	485,071	555,727	466,913	1,629,836
1924–1925	3,252,954	1,090,000	88,483	660,411	769,000	779,510	2,297,404
1929–1930	3,804,023	1,018,000	200,000	866,110	912,357	981,371	2,959,838
1930–1931	3,950,386	1,208,000	184,000	783,163	988,612	958,032	2,913,807
1931–1932	4,339,232	1,156,000	156,617	992,335	1,025,354	1,174,311	3,348,617
1932–1933	4,605,219	1,357,000	222,760	816,337	1,035,546	1,342,795	3,417,438
1933–1934	5,290,101	1,642,000	205,000	1,103,822	952,186	1,580,443	3,841,451
1934–1935	3,811,087	1,154,000	234,000	784,000	952,000	824,000	2,794,000

* Yearbook of Agriculture, 1935.

Sugar has risen to a place of large importance as a food among all civilized nations, both from the standpoint of value and per capita consumption. In the early days of cane-sugar refining, sugar was a very rare and expensive substance, used only as medicine and condiment by the most wealthy. Its cost was at least a hundred-fold the price now obtained for a much improved and distinctly purer product.

Cane sugar is produced from a plant which is a member of the grass family, Graminaceae. This plant is doubtless one of great antiquity because records of the army of Alexander indicate that sugar cane was observed during his campaign in India several centuries before the Christian era. It is believed that the cultivation of sugar cane spread westward and reached the Mediterranean countries during the eighth century.

Sugar was introduced into the West Indies by the end of the fifteenth century, and it is sometimes stated that Columbus carried samples of cane there at the time of his second westward voyage. It was not until the latter part of the eighteenth century that sugar cane was introduced in Louisiana, our most important cane-sugar-producing state.

The cultivation of sugar cane requires tropical or subtropical temperatures and a great deal of rain. This limits the production to those regions within, or adjacent to, the isotherms of 68°F.

British India is by far the largest cane-sugar-producing country, followed by Java and Cuba. The United States produces a relatively small cane-sugar crop within its own boundaries, although the production of the Philippines, the Hawaiian Islands, Puerto Rico, and the Virgin

Islands combine to make the United States one of the most important in the industry. Other countries which have large cane-sugar crops are Brazil, Japan (including Formosa and Korea), Dominican Republic, Haiti, Peru, and Argentina.

TABLE 59.—PRODUCTION OF CANE SUGAR 1932–1933
(Thousands of tons)

British India	4,727
Java	2,759
Cuba	2,053
Philippine Islands	1,164
Hawaii	933
Brazil	925
Japan	795
Puerto Rico and Virgin Islands	755
United States	240
World total	26,331

There are many varieties of sugar cane, each being grown in the region which is most favorable because of climatic and soil conditions or resistance to the diseases of cane prevalent in that area. The color of the plant may be green, yellow, pink, red, purple, or striped combinations of some of these colors. It grows from about 5 ft. in height to a length of 25 or 30 ft. in exceptional instances, although the more common varieties range between 10 and 15 ft.

Sugar cane is generally propagated by cuttings from the stalk, rather than by planting seeds. Sections of the stalk, each containing a bud located at a node or joint, are planted in the ground with a shallow covering of earth. Growth develops from the bud, giving rise to several shoots which are collectively known as a stool. Diameter of the stalks varies from 1 to 3 in., depending on variety, soil, climate, and length of growing season. The plant itself is a perennial and will develop new cane for many years. As decreasing yields result from subsequent cuttings, it is not feasible to harvest cane for more than a few years from one planting. The first crop after planting is known as plant cane. Later crops from the same planting are known as ratoons.

The length of time the cane is allowed to grow before harvesting varies in different countries. In Louisiana the harvesting generally starts after seven or eight months' growth, while in Hawaii the time varies from one and a half to two years. Exceptionally dry or cool weather hastens the maturity of the cane and tends to shorten the normal growing season.

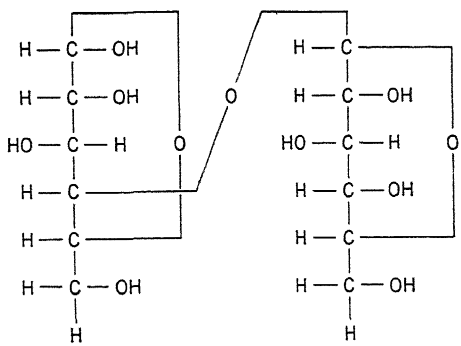
The harvesting of cane is usually started before the crop is fully matured in order that the entire crop may be disposed of before it has passed the optimum state of maturity. The stalks are cut off just above the ground or in some instances a little below the ground level. The tops of the stalks are chopped off because the upper portions yield lower

returns in juice. The leaves are usually stripped from the stalks manually. In some areas the leaves are burned off, which saves labor but hastens deterioration. Burning is advantageous when the fields have weed growths which are objectionable. Cane from burned fields is particularly subject to spoilage during the wet weather because the action of microorganisms is favored by such conditions.

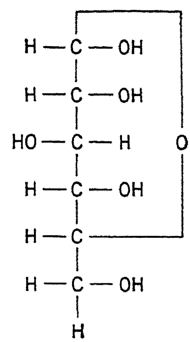
Under any circumstances, the sooner the cut cane is hauled to the mill and utilized, the higher the yield of sucrose will be. The quantity of sucrose is lessened by the action of enzymes which invert this sugar which contains 12 carbon atoms into one molecule of dextrose or glucose and one molecule of levulose or fructose, each of which contains 6 carbon atoms. The enzyme invertase is present in the grain top of the cane and may diffuse into the body of the cane, causing this change.

The chemical structure of certain food sugars is shown below.

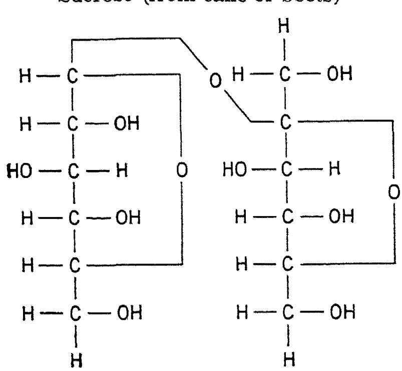
Maltose (from grain)



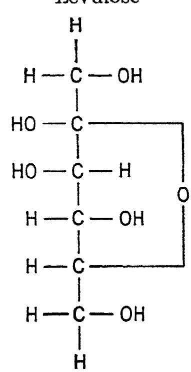
Dextrose



Sucrose (from cane or beets)



Levulose



Enzyme action progresses more rapidly at higher temperatures such as those common in tropical regions so the time element is important

because the product desired is sucrose rather than the invert sugar. Microorganisms which are always present on the cane also cause a lowering of sugar content because the enzymes which they produce are capable of converting sucrose into the monosaccharides. The sugars are also converted into acids by the same types of organisms, and acidity favors the conversion of sucrose by accelerating the action of enzymes.

Cane is transported to the factory, mill or "central" by means of carts, cars, boats, flumes, aerial ropeways, and by pack animals. Mules, oxen, and tractors are used to haul the carts. Cars on narrow-gauge tracks are motivated by mules, motors, or small steam engines. Fluming is a method particularly adapted to the Hawaiian Islands, while the use of aerial ropeways is largely confined to hilly regions such as Mauritius.

Crushing.—When the cane reaches the mill, it is first subjected to a process of slicing, shredding, or chipping which mechanically reduces the cane to pieces of small size. This operation is not primarily for the purpose of obtaining juice, but to facilitate extraction in the crushing process which follows. Crushers consist of two or three grooved or toothed rolls through which the shredded cane is passed.

There are generally three or more sets of three-roller mills employed in pressing out (or extracting) the juice from the cane. By the time the cane has gone through the crusher and the first mill about 60 per cent of the juice has been removed. The succeeding mills express additional quantities of juice. To facilitate the removal of as much juice as possible, it is the custom to add water or dilute juice to the cane before the final regrinding and milling. The woody fiber left as a residue is known as *bagasse* or *megasse.*

The fiber fragments present in the expressed juice are removed by means of mechanical strainers or juice screens which may be perforated brass plates or wire cloth of stainless metal with devices to remove automatically the fragments and convey them to other mills where the juice contained in them will be removed. The bagasse may be used as fuel for the boilers of the factory or may be dried and used as a source of raw material for insulating board or wallboard for the interior of houses.

Purification of the Juice.—The purpose of purification, also called clarification or defecation, is to remove the largest possible amount of impurities from the juice at the start. Clarification is effected by the use of lime and heat. The amount of lime used, the way in which it is added, and the temperature to which the juice is heated are variable factors depending upon the region and conditions. The more common way of adding lime is that of mixing a definite amount in the form of milk of lime ($Ca(OH)_2$) with a weighed quantity of the cold juice. The exact amount of lime to be used, until recently, was determined by various methods employing different indicators and titrating. It is now com-

mon to adjust the juice to the desired hydrogen ion concentration by means of pH determining apparatus. Best results are obtained when the pH of the cold juice is brought up to 8 or 8.5. Some of the factors which must be considered in regulating pH of the juice are; inversion of sucrose, destruction of glucose, clearness of the juice, the increase in purity, and the volume of settling.

The temperature is generally raised to boiling after liming. A flocculent precipitate containing calcium phosphates and other insoluble salts carries down the finely divided material in the juice, including coagulated albumin, fat, gum, and wax. The juice is then permitted to settle and the clear liquid decanted. The mud, slops, or sludge which remains is pressed in a filter press, and the juice extracted by the filters is mixed with the purified juice. The combined clarified juice is evaporated in multiple-effect vacuum evaporators to a sirup containing about 35 to 45 per cent of water.

Crystallization.—The concentrated juice, or sirup, is further evaporated until it is saturated with sugar, the process also being carried out in vacuum pans. When the sirup becomes saturated, crystals of sugar separate out. As water evaporates, more sirup is added to the pan and sugar is deposited on the crystals already formed. The mass of sirup and sugar crystals finally obtained is designated by the sugar manufacturers as "massecuite," or magma.

Centrifuging.—The massecuite, magma, or melada is placed in centrifugals with perforated metal baskets which have a lining of wire cloth and perforated bronze sheets. Crystals of sugar remain in the basket while the liquor, molasses, is thrown out through the perforations by centrifugal force. The crystals of sugar are brown and some sirup still adheres. This sugar, known as raw sugar, may be further prepared for consumption by refining. The molasses still contains crystallizable sucrose and is therefore mixed with sirup and returned to the vacuum pans. The new massecuite is centrifuged and the molasses again returned to the vacuum pan to be treated as before. After the centrifugal treatment has been repeated three times, the higher quality A and B sugars are ready to be bagged and the C sugars, of lower grade, are returned to the vacuum pans as seed for more A and B sugars. Molasses of such low sucrose concentration that removal of sucrose is uneconomical is called blackstrap and is largely used in the fermentation industries. In 1933 over 200 million gallons of molasses was imported by the United States.

The Refining of Sugar.—Raw sugar is transported in jute bags to the refineries, which in this country are located near the seaports. Sugar from the West Indies comes in jute bags of 300 to 330 pounds capacity; from Central America and Hawaii in smaller bags of the same kind. The

sugar in each bag is weighed and a sample taken by the customs officials who determine the duty to be paid by the percentage of sucrose present.

The sugar is dumped from the bags into a hopper from which it is removed for the washing process which follows. The sugar bags are washed with hot water to recover the sugar adhering to them after they are emptied. One refinery located in Boston installed mechanical conveyors on its docks and in its boats in 1933 and now transports its sugar from the tropics in bulk in the hold of the vessel, thereby eliminating much of the extra labor necessary in handling the bags.

Washing.—The first real refining process is that of washing the raw-sugar crystals, and is often referred to as affination. The crystals are surrounded by a very thin layer or dried film of adhering molasses. The film is removed by mixing the raw sugar with sirup of about 70 to 72° Brix, centrifuging, and washing the crystals with water.

The mixture of raw sugar and sirup is run into centrifugals similar to those used in the raw-sugar factory. The washings go into the sirup and part of this is again used as wash sirup for mixing with more raw sugar. It is necessary, however, to dilute the sirup to 70 to 72° Brix and raise its temperature to 120°F. before using it again as a sirup for purging.

In refineries where centrifuging is continuous, any accumulated wash sirup is removed completely and fresh water substituted as at the start of the washing period, once every 24 hours.

Melting.—The washed sugar is dropped into a melter with water and dissolved with the aid of mechanical stirrers and heat, usually in the form of exhaust steam. The amount of water used is about 50 per cent of the weight of sugar used.

Defecation.—The washing and purging processes remove only surface impurities from the raw sugar and the liquor from the melters is acid in reaction. Defecation is brought about by the use of lime, which is added until a pH of 7.3 to 7.6 is obtained. The temperature is raised to 180°F. and the lime allowed to neutralize the acids present. A precipitate is formed which carries down the finely divided suspended matter, including such pectins, albumins, and gums as are present.

Kieselguhr, diatomaceous earth, or sometimes paper pulp is mixed with the sirup and the solution run through pressure filters to remove all suspended solids. This treatment does not remove color, but the effluent should be clear.

Before pressure filters were available, the defecation was accomplished by means of treatment with phosphoric acid and lime and subsequent filtering through bag or stocking filters. Pressure filters are preferred as less labor is required in cleaning.

Treatment with Bone Char.—Boneblack or animal charcoal is used primarily to remove the coloring matter from sugar. Color removal is

principally by adsorption. It is also of some importance in removing organic and inorganic impurities.

The charcoal filters are cylindrical, about 10 ft. in diameter and 20 ft. tall, and conical at the bottom and top. Near the bottom are two manholes, for the purpose of removing exhausted charcoal. On the top of the filter, there is a movable door or filter head. A coarsely woven cotton blanket is placed over the perforated plate which rests just above the bottom of the filter over the outlet of the tank. Over the blanket is another of finer weave, which serves to retain the charcoal. The sugar liquor heated to 160°F., is run into the filter charged with boneblack, at the side of the top of the filter. When the filter is full, the cover is fastened on and filtration continued through a pipe connection, under pressure. It requires from 3 to 8 hours for the liquor to flow through the filter.

It is customary to use approximately 0.5 to 1.0 lb. of boneblack for each pound of melted sugar. If the process is to be continuous, some boneblack must be revivified while the rest is in use. The filters are cleaned by running hot water (210°F.) through them. Wash water containing sufficient concentrations of sugar is saved, the rest is discarded. When the filter has been washed, the exhausted char is removed through manholes near the base of the filters and revivified by passing into kilns heated from 1,000 to 1,200°F. by means of gas, oil, or coal. The char is heated in the absence of air to prevent it from being oxidized, and impurities not removed by washing are burned out in this process. The char is then cooled to 160°F. before being returned to the filter to be used again. In 1934 a mechanical separator for removing exceptionally dense particles having little or no active surface, also very small particles of char, was developed in a Boston refinery by Brown and Bemis, which increased the filtering efficiency of the char as both very dense as well as very small particles impair filtration.

Boiling.—Boiling is the process of graining or crystal formation and is carried out in large vacuum pans. If a small volume of liquor is used for graining, a small number of finished crystals result. As more liquor is added to the vacuum pans after the pan is "grained," *i.e.* crystals have formed, the number of crystals does not increase but the crystal size does, as sugar is deposited on those already formed. Thus when large crystals are desired, a small volume of liquor is used at the start and a small number of crystals allowed to form, which is called "graining lowdown." If, on the other hand, a large volume of liquor is placed in the pan initially, the resultant finished crystals are small. The control of temperature and vacuum during this process is most important to attain the desired result, and the boiling operation requires the constant attention of skilled and experienced operators or "sugar boilers" to get the desired "grain."

Granulated or other hard sugars require a pan temperature of 160 to 180°F. For soft sugars the temperature maintained is 120 to 130°F.

Finishing or Curing.—The material from the vacuum pans is centrifuged to separate the sirup from the crystals of refined sugar. Water or sometimes steam is applied in the centrifugals to wash the crystals free from sirup. The washed crystals are next conveyed to a granulator to dry and separate them. The granulator is a drum made of iron about 6 ft. in diameter and 20 to 30 ft. long and inclined slightly from the horizontal. Along the inside of the drum are saw-tooth shelves attached lengthwise. As the drum revolves, these shelves lift the sugar and cause it to drop through the heated air, which enters at the lower or discharge end of the inclined drum. Generally two drums are located one above the other. The sugar is heated and partly dried in the upper drum. But little heat is required to complete the drying in the lower drum, and consequently the sugar leaves relatively cool. Not infrequently a third drum is connected with the first two for the purpose of further cooling the sugar.

The dried granulated sugar is sieved and classified according to the size of the crystal, using screens. Lumps and dust are removed by the screening process.

Grading.—Granulated sugar is classified as extra coarse, coarse, medium, fine, and extra fine, according to the size of the crystals. The sugar most generally found in the market is the fine and extra fine granulated. The larger sizes are more commonly used in Europe.

Packing.—Sugar is packed in 100-lb. cotton and burlap bags, barrels, or small cotton bags, paper packages, and cartons for the retail trade. Some is pressed in cubes for table use.

BEET SUGAR

The sugar beet is also an important source of sugar. It is said that the Chinese were probably the first people to make use of the beet as a source of sugar, although Germany is credited with the first commercial process actually used for this purpose. A few years later (1810) Napoleon stimulated interest in sugar by the offer of a large prize for the best method of sugar production in France. Much effort has been spent since that time on the development of processes of extraction as well as improvement in the sugar beet as a source of sucrose. The present-day sugar beet may contain 16 to 20 per cent sucrose, about threefold that of Napoleon's time.

The yield of sugar per acre is considerably less from the beet than from cane, but the culture of beets is possible in regions where cane cannot be grown. Sugar beets grow best in temperate climates but are successfully

grown in the high altitudes of warmer countries also. A long and moderately cool growing season is desirable. Climatic conditions which enable rapid growth during the vegetative development of the beet, followed by a cooler period with warm sunny days but cool nights having only slight rainfall, are optimum for sucrose production.

The by-products of beet-sugar manufacture include beet pulp which is a valuable stock food and the forage available from the beet tops and crowns left in the field. The latter may be used for ensilage.

TABLE 60.—BEET-SUGAR INDUSTRY—PRODUCTS BY KIND, QUANTITY, AND VALUE FOR THE UNITED STATES, 1929*

	Tons (2,000 lb.)	Value
Aggregate value.		$108,552,581
Sugar:		
Total.........	1,086,055	100,767,031
Granulated.	1,068,285	$100,249,231
Unfinished..	17,770	517,800
Molasses:		
Total......	77,781	1,169,257
Discarded from desugarization process (exclusive of that used for molasses beet pulp)...............	53,472	789,615
Other, sold for purposes other than desugarization	24,309	379,642
Beet pulp..	1,460,597	5,230,795
Dried pulp, exclusive of molasses pulp.	87,536	2,127,354
Moist pulp..........................	1,297,368	1,124,038
Molasses pulp.......................	75,693	1,979,403
Other products......................		1,385,498

* Census of Manufactures, 1929, vol. 2, U. S. Dept. Comm. Bureau of the Census.

Germany, Russia, United States, Czechoslovakia, and France produce the largest quantities of sugar beets. In the United States the Mountain states produce about 60 per cent of the crop. The North Central states furnish about 30 per cent and the Pacific states some 10 per cent.

The early steps in the manufacture of sugar from beets are quite different from those for cane sugar. The beets are removed from the ground and the crowns and tops removed. The beets are transported to the factory where the roots are cut into thin slices from which the sugars are removed by diffusion with warm water. In this process the membranes of the beet cells act as dialyzing membranes which enable the sugar of the beets to diffuse slowly into the water in which they are submerged. The colloids, which make up a considerable part of the com-

ponents of the beet cells, are relatively incapable of diffusing through the cell membranes and so are not removed to any extent.

It is impossible to remove all the sugar in any mass of cut beets by a single diffusion process. The water must be entirely changed a number of times, usually 10 or 12, and each successive fresh volume of water can remove only a part of the sugar remaining in the beets, even though the sugar percentage in the beets is lowered by each extraction. In order to lessen the volumes of water used, a series of diffusers or tanks are arranged in batteries with pipe lines so that water may be run from one tank containing beets to the others. Fresh water is run into the diffuser containing beets with the lowest sugar concentration (those which have already been extracted a number of times) and when all the sugar which can be extracted from them is obtained, the water is used again. This time the water is pumped to a tank containing beets with a higher percentage of sugar, under which conditions the water takes on a little more sugar. This process may be continued, each time in contact with beets containing higher sugar concentrations until it is finally used on beets containing the highest amount of sugar, namely, beets which have had no previous extraction. This system enables an efficient utilization of water and at the same time an efficient extraction of the sugar with a final liquor rich in sugar. The water is generally maintained at a temperature of about 165°F. to increase the rate of diffusion somewhat and at the same time cut down the incidence of action by microorganisms. The water solution or sirup obtained from the last diffuser is strained and any remnants of pulp removed. It is then treated with lime and carbon dioxide and heated to remove other impurities, particularly acids which are neutralized by the lime, and organic materials including coloring substances which are precipitated. Subsequently the sirup is given a sulphite treatment, which lightens the color and improves the keeping quality. The product is then filtered and the filtrate concentrated in vacuum pans. The final technical processes in the making of granulated sugar are similar to those described above for cane sugar.

According to Pack, the storage of normal sugar beets may be conducted with best results at temperatures slightly above freezing (1.7°C.) in a moist atmosphere. The use of proper moisture conditions decreases the loss of sugar which will take place under dry conditions.

In the Oxford processes of beet-sugar manufacture the dehydrated beet cossettes which are used as a source of sugar must be treated differently from raw beets. The juice is extracted in the same general manner but has a concentration of about 50°Brix, about four times that obtained from raw beets. The juice is limed until it is slightly alkaline, then centrifuged to remove all the impurities in suspension. It is then passed through bone char and then into the vacuum pans and is said to produce

a high-quality white sugar. Numerous technical and economical advantages for this process are cited by Owen.[1] The methods of dehydrating beet cossettes are discussed in the chapter on dehydration.

LEVULOSE

Another sugar which has attained more importance in recent years is levulose or fructose, a ketose-hexose, in part because it has been found that patients having diabetes have a higher tolerance for levulose than for dextrose or sucrose. The structural formula for levulose is shown on p. 155. Although invert sugar formed by the hydrolysis of sucrose, cane sugar, contains equal parts of levulose and dextrose, the production of levulose is attained more satisfactorily from sources which contain as their main carbohydrates levulose or its polymers. Jerusalem artichokes, chicory, and dahlia roots are among such sources.

The Jerusalem artichoke, or wild sunflower, has been found to contain from 8.6 to 19.4 per cent levulose, with an average, in Iowa, of about 14 per cent.[2]

Experiments carried on at the Iowa State College[3,4] have resulted in methods by which good yields of levulose may be obtained from the Jerusalem artichoke (*Helianthus tuberosus*) and a satisfactory process for sirup from the same origin has been developed recently at the University of Illinois.

The artichokes are usually dehydrated in slices soon after harvesting in order to prevent lowering of sugar content until the product may be used, at which time the slices are extracted with water in a manner similar to beet-sugar extraction. The resulting extract containing the plant carbohydrate is acidified to a pH of 1.5 by adding sulphuric acid, and hydrolyzed for an hour at 80°C. The pH is adjusted to pH 7.5 after the heating by the use of powdered hydrated lime, which causes a precipitate of calcium sulphate. The extract is filtered to remove this precipitate together with coagulated proteins and colloidal material. The filtrate is then treated with a lime suspension forming lime levulate which is filtered and washed, then suspended in distilled water, and carbonated under pressure of 15 lb. at 15°C. The resulting levulose solution is filtered to remove the precipitated calcium carbonate and then evaporated in a vacuum pan at 60°C. to a 40 per cent sirup. After being filtered again, the sirup is concentrated to 90 per cent. Crystallization takes place and the temperature is gradually reduced. The resulting massecuite is

[1] OWEN, B. J., *Food Ind.*, **1**, 699, 1929.

[2] LINCOLN, A. T., *Science*, **80**, 463, 1934.

[3] MCGLUMPHY, J. H., J. W. EICHINGER, R. M. HIXON, and J. H. BUCHANAN, *Ind. Eng. Chem.*, **23**, 1202, 1931.

[4] EICHINGER, J. W., J. H. MCGLUMPHY, J. H. BUCHANAN, and R. M. HIXON, *Ind. Eng. Chem.*, **24**, 41, 1932.

centrifuged in order to separate the levulose crystals and the molasses which is sweet and of light color. The crystalline material has a content of over 98 per cent levulose.

Sirup may be made from dried artichokes which are extracted with water. The extract is treated with Super-Cel and filtered, using a filter press to remove the suspended matter. The acidity of the filtrate is adjusted to pH 4.5 with hydrochloric acid and the solution hydrolyzed at 25 lb. pressure for 20 minutes. After hydrolysis, the solution is concentrated to a 60 per cent sirup in a vacuum pan, neutralized with sodium carbonate, filtered, and further concentrated to the desired extent.[1]

SIRUPS

The following Federal definitions for various sirups and related substances indicate the proper usage of terms which are sometimes rather loosely applied in the food industries as well as by the consumer.

Massecuite, melada, mush sugar, and concrete are products made by evaporating the purified juice of a sugar-producing plant, or a solution of sugar, to a solid or semisolid consistence, and in which the sugar chiefly exists in a crystalline state.

Molasses is the product left after separating the sugar from massecuite, melada, mush sugar, or concrete, and contains not more than 25 per cent of water and not more than 5 per cent of ash.

Refiners sirup is the residual liquid product obtained in the process of refining raw cane sugars, and contains not more than 25 per cent of water and not more than 8 per cent of ash.

Maple sirup is sirup made by the evaporation of maple sap or by the solution of maple concrete, and contains not more than 35 per cent of water, and weighs not less than 11 lb. to the gallon (231 cu. in.).

Cane sirup is sirup made by the evaporation of the juice of the sugar cane or by the solution of sugar-cane concrete, and contains not more than 30 per cent of water and not more than 2.5 per cent of ash.

Sugar sirup is the product made by dissolving sugar to the consistence of a sirup and contains not more than 35 per cent of water.

Sorghum sirup is the sirup obtained by the clarification and concentration of the juice of the sugar sorghum and contains not more than 30 per cent of water, nor more than 6.25 per cent of ash calculated on a dry basis.

It is evident that maple sirup, cane sirup, and sorghum sirup differ from the others mentioned above in that each is obtained by evaporation of the juice from a sugar-producing plant or by dissolving the sugar or solidified concrete thus made to the consistency of sirup. These differ from molasses in that they are the direct result of concentrating all the sugar of the original sap with sufficient associated plant components to

[1] Dykin, F. A., E. C. Kleiderer, V. Heubaum, V. R. Hardy, and D. T. Englis, *Ind. Eng. Chem.*, **25**, 937, 1933.

Dykin, F. A., and D. T. Englis, *Ind. Eng. Chem.*, **25**, 1165, 1933.

result in a distinct character and flavor, whereas molasses is a by-product consisting primarily of noncrystallizable sugars and other material.

Cane and maple sirups have been made in this country since the days of the first settlers and were quite important products up to Civil War times. In later years they have been replaced to a considerable extent by other more highly refined sugar products, although maple sirup is still highly esteemed in New England and cane sirup is popular today in the South for special purposes.

Cane Sirup

Cane sirup has been known for over a thousand years. It was used as a substitute for honey and first attained use because of its sweet flavor and reputed medicinal value. The Spanish made efforts to introduce this plant into the West Indies soon after the first voyage of Columbus and it was first planted in San Domingo in 1494. The first plantings in Louisiana were about 1751, although the culture of cane in Florida was started much earlier.

Cane sirup has been made to a considerable extent in small mills in the states bordering upon the Gulf. The extraction equipment is crude compared with that used in the large sugar refineries and the concentration is done in open kettles or evaporators rather than in vacuum pans. The product is rarely clarified except by skimming the tops of the kettles, but nevertheless the resulting sirup is generally of a distinctive and pleasant flavor. With no uniformity in processing and many factors which are variables concerning the raw material, such as variety, maturity, soil in which the crops are grown, and the like, it is not surprising that cane sirups differ greatly in character and composition. The cane sirups which have attained any widespread distribution have been those which have been blended in large quantities so that the sirup marketed was of fairly uniform appearance and flavor.

The standard grinder in cane-sirup manufacture is the three-roll mill, the opening at the feed side being 3/8 or 1/2 in. and at the finishing side, 1/16 in. The feeding may be done by hand or from a belt, the bagasse is carried off and delivered on a wagon, or it may be dropped on a pile. Owing to the fermentation, which is sure to take place, it is better that it be discharged directly on a wagon and hauled away from the plant.

The juice is conducted to settling tanks to be drawn off into the kettles or evaporating pan.

The oldest evaporating device consisted of large iron kettles mounted in a masonry furnace. These varied from 100 to 250 gal. capacity and one, two, or three mounted together. This method is nearly obsolete now. The difficulties are the long time required for reducing a batch, from 3½ to 5 hours, lack of good skimming on account of the volume,

more or less burning of the sirup on the kettle during the last third or quarter period, darkening of the sirup owing to the prolonged heating, and some overheated or burned flavor. The advantages are that it is a very simple and inexpensive outfit and wood of almost any character can be used as fuel.

The next distinctive improvement was the development of the open evaporators. These consist of long shallow pans, ordinarily about 15 ft. in length, 3 ft. in width, and 6 in. in depth mounted over a brick firebox. The pan is most often of copper or galvanized iron and has a series of cross partitions which are incomplete but act as baffles to cause a longer travel for the juice in passing from one end to the other. The pan is set at a slight incline so that the receiving end will be lower than the overflow end, the depth of the juice in the former being about 2.5 in. and in the latter about 1 in. (It is immaterial in which direction the pitch is made.) The settled and filtered juice is permitted to enter at such speed as to be practically finished at the overflow, so that the operation becomes continuous. Like the kettle, the skimming must be done by hand, but as the juice is in a thin layer, the separation is better. Most of the skimming is done on the first third of the pan.

In the larger and more expensive pans the heating is done with steam coils in the pan instead of by direct fire. The advantages are gradual heating of the juice, which favors clarification, ease in skimming, rapid evaporation, heating of any part of the juice for only a relatively short time, and continuous operation.

The raw juice is filtered through cloth as it leaves the mill in order to remove any bits of tissue and any particles of dirt which may have been loosened in the crushing.

The yield of juice per ton for the small mills is figured at 60 per cent, or 1,200 lb. per ton, which is high rather than otherwise, and hence a 10-ton mill will have a rated capacity of 12,000 lb. of juice per day.

The juice naturally contains some soluble solids other than sugar, but the proportion is so small that the total solids are expressed in degrees Brix, or Baumé, preferably the former. The ordinary range of juice is from 14 to 16°Brix, but it may run higher or lower, depending upon the conditions when the stalks are cut, variety, season, etc., but the average is not far from 15 per cent and that is accepted as a representative figure. In order to make sirup, the juice must be concentrated so that it will test between 71 and 72°Brix at ordinary temperature (70 to 72°F.). This makes the ratio nearly 5 parts of raw juice to 1 of the finished product which is further widened by losses in skimming, as is clearly evident in practice, since one ton of cane yielding 1,200 lb. of juice will produce but 20 gal. of sirup weighing 11.25 lb. per gallon or 225 lb., representing a ratio of 5.3:1.

The temperature at which the sirup boils corresponds to the concentration and this is a particularly convenient method of checking the finish as the thermometer bulb is kept permanently in the hot material. The temperature for finishing in the entire cane-belt region is between 223 and 224°F.

The overflow passes through a fine wire screen into a receiver and is held until a sufficient amount accumulates to fill a lot of cans. The best temperature for filling gallon cans is about 160°F., but for smaller cans it may be higher. If the time required to accumulate a batch of sirup is more than an hour, as it usually is in small plants, it is best to cool the sirup by running it through a jacketed pipe or over a milk cooler. The color becomes darker and the flavor takes on a cooked character if this precaution is not taken.

Sirup made from clean cane, handled promptly from the cutting and through the factory, and not ground with pressure sufficient to extract more than 60 per cent of juice, may be canned directly with little trouble other than possible separation of sugar crystals in the sirup. With some of the varieties of cane yielding appreciable quantities of invert sugar, even this difficulty is eliminated. The cans are filled at about 160°F., sealed, and given a short cook, 10 minutes at 185°F., as a measure of safety against infection from the final handling and the container. Many packers do not cook after canning, but it is an added factor of safety that is worth while.

Cooling after cooking is a second precaution. Owing to the nature of the product, it holds heat for a long time and unless cooled, the flavor may be affected. It is a product attended by springers while in the trade, and these can be prevented in part or the time deferred by hot filling of the cans and cooling immediately after sterilizing. This form of springer is ascribed to chemical changes in the product and prolonged retention of heat favors the condition.

The cans used are Nos. 1½, 2½, 5, and 10, and they are of plain tin.

Bottles of pint and quart sizes are excellent packages for high-grade sirup, and the handling is the same as for cans except that the filling is usually done at about 140°F. and more time is given in the sterilizing bath.

Large Production Plants.—Small unit-production plants give the quality of sirups most satisfactory to cane growers who are familiar with cane sirup, but it is expensive in labor and fuel as measured by standards in volume production. Therefore equipment has been designed to handle larger volume so as to approximate the same quality in the sirup. Some technical control is needed in the larger plants, whereas those handling from 10 to 30 tons per day depend upon an experienced operator and such simple tests as he may use. The difference in the methods will be discussed in the order occurring in the manufacture.

First, a heavier grinder is used and more pressure applied in order to increase the yield of juice, but with a deterioration in flavor, so that it is not desirable to exceed 60 per cent juice, as it is better to sacrifice yield rather than quality. Hard pressing also increases the acidity of the juice, which is undesirable.

The juice is strained through a fine wire screen or coarse cloth in order to remove appreciable particles, but instead of allowing the juice to stand, it is at once subjected to the action of sulphur dioxide. The older method, and an effective one, is to use a small tower with numerous baffles inside over which the juice flows in a thin layer, a large surface thus being exposed to the sulphur. The juice is first tested for the natural acidity, then pumped to the top of the tower, which is ordinarily about 20 ft. in height and 1 ft. in cross section inside. The fumes from burning sulphur enter at the bottom and the juice absorbs a quantity in its passage downward. The total acidity, *i.e.*, the amount normal to the juice plus that absorbed from the gas, should not exceed the amount required to neutralize 3.5 cc. of one-tenth normal alkali in a 10-cc. sample. Phenolphthalein is the indicator. If the juice is too low in acidity, it can be run through a second time; if too high, it can be diluted with untreated juice. Too much sulphur gives a sharp flavor.

Instead of the tower, the sulphur dioxide may be obtained in cylinders and introduced into the juice through a pipe distributor which at the same time agitates the mass.

Immediately after sulphuring, the contents of the tank are treated with strained milk of lime. The amount used must be below that required for neutralization. It is best to keep the acidity such that about 1.5 cc. of one-tenth normal alkali will neutralize a 10-cc. sample. The juice is well agitated, then heated by a coil to near the boiling point, skimmed, and after about 5 minutes the procedure repeated. If necessary, a third heating and skimming may be given, though two usually suffice. The juice is allowed to stand in the clarifier for an hour and then drawn off from about 2 in. above the bottom. The sulphur has the effect of decolorizing and of giving a brighter product, and the lime that of precipitating the gums and other nonsugar solids. The combined result is a juice which can be worked through the evaporator more rapidly, resulting in a better appearing finished sirup.

Evaporators using steam coils are used for the larger operations, but as in the smaller, the juice is worked through in a thin layer in order to get rapidity of evaporation and the best possible appearance. The steam lines may be equipped with automatic-control devices so that the work is continuous and constant and the final product nearly uniform.

In lieu of the evaporator, the vacuum pan may be used after the juice has been boiled and settled.

Standardizing.—Sirup produced on a small scale is standardized and repacked for shipment. The mixed lots are inspected, tested for acidity, sugar, and color, and then mixed as judgment indicates. They are then treated with vegetable carbons prepared for the purpose. The sirup is heated, the carbon incorporated by agitation, and the solution then pumped through a filter press. The treatment results in a brighter colored sirup but is accompanied by some loss of flavor so that it more nearly approaches that of simple sugar sirup. The cost of clarification by this method is decidedly higher than by the sulphur and lime treatment.

The most recent addition to the equipment of the sirup canner is the use of invertase to convert a small part of the sucrose into invert sugar and thus prevent crystallization in the sirup. Since invertase is an enzyme, a small quantity will act upon a large quantity of sirup and have the desired effect without changing its quality or affecting its flavor as a food. The treatment may be used when the sirup is about one-half boiled, and that seems to be the preferable time when making the sirup, or when the blending operation is carried out in finished sirups. The semisirup or sirup is run into large tanks and heated to about 145°F. The invertase is added in the proportion required by the particular preparation but ordinarily at the rate of about 1 lb. to 300 to 400 gal. It is well mixed and allowed to stand about 12 hours. The tanks are covered and insulated so that the loss of heat is retarded. The semisirup is then finished and the product is ready for canning. The blended sirup is ready for canning at once.

According to the 1931 Census of Manufactures, cane sirup was manufactured to the extent of 3,550,000 gal. in the United States. These figures do not include any establishments which produce less than $5,000 per year in value of products and doubtless thereby exclude numerous cane-sirup manufacturers. All but one of the 68 establishments manufacturing cane-sugar products were in Louisiana.

Maple Sirup

Maple sirup is one of the real American products unknown to the white man before his arrival on this continent. The method of preparation had been developed by the Indians and represents one of the highest attainments in their culinary art. They also used the product as an article of barter between tribes.

The whites learned the method of preparation from the natives and at once applied themselves to improve upon it. The use of the auger in tapping the tree, spiles made from stems of the elder, and short troughs made by splitting a tree and cutting out a part were all possible with the tools which they possessed, and far in advance of anything which the

Indian could do by breaking limbs and bending them down so they could catch the drip or by notching the tree in some cases. Even with the small kettles which the immigrants brought with them, they succeeded in making enough sugar for their needs and to be independent of imports of cane sugar. Maple sirup and sugar became important articles of manufacture for home use in the northeast section of the country, and remained so until about 1875.

TABLE 61.—PRODUCTION AND PRICE OF MAPLE SUGAR IN THE UNITED STATES*

Year	Trees tapped, 1,000 trees	Sugar made, 1,000 lb.	Sirup made, 1,000 gal.	Total product in terms of sugar, 1,000 lb.	Average total product per tree		Price per pound of sugar, cts.	Price per gallon of sirup, dollars
					As sugar, lb.	As sirup, gal.		
1917	17,313	10,525	4,258	44,589	2.58	0.32	....	....
1918	19,132	12,944	4,863	51,848	2.71	0.34	....	....
1919	16,639	9,541	3,262	35,637	2.14	0.27	....	....
1920	16,672	6,928	3,131	31,976	1.92	0.24	....	....
1921	14,160	4,699	2,149	21,891	1.55	0.19	....	....
1922	15,198	5,227	3,370	32,187	2.12	0.26	....	....
1923	14,178	4,656	3,262	30,752	2.17	0.27	....	....
1924	14,193	4,096	3,574	32,688	2.30	0.29	26.0	2.00
1925	14,070	3,238	2,817	25,774	1.83	0.23	26.9	2.08
1926	13,948	3,585	3,504	31,617	2.27	0.28	29.3	2.12
1927	13,751	3,183	3,429	30,615	2.23	0.28	28.7	2.05
1928	13,489	2,189	2,782	24,445	1.81	0.23	28.6	2.02
1929	12,858	1,362	2,361	20,250	1.58	0.20	30.0	2.03
1930	13,062	2,370	3,641	31,498	2.41	0.30	30.1	2.03
1931	12,138	1,646	2,213	19,350	1.59	0.20	25.7	1.72
1932	12,091	1,623	2,412	20,919	1.73	0.22	24.5	1.51
1933	12,076	1,288	2,186	18,776	1.55	0.19	20.8	1.18
1934	12,158	1,271	2,395	20,431	1.70	0.21	24.7	1.33

* Yearbook of Agriculture, 1935.

Maple sirup is a product, limited by nature to that made from the sap of a few types of trees, *Acer saccharum* and its three or four varieties. While these are distributed widely over a large part of the country, they occur in abundance only in the northeast section and southeastern Canada. The tree is of such slow growth that it would not be profitable to make plantings for sirup production, so that dependence remains upon the natural forests, and these are disappearing. A further limitation is that of climate. Sap flows for only a short time in the spring and in some seasons it can be obtained on only one or two days, and in other years at intervals over two weeks or more. At its best it is irregular. In many

places it is never worth the labor to open a camp. By modern methods of tapping, metal spouts, buckets with covers, and shallow evaporators, a higher yield is obtained from the same number of trees than formerly, but it is destined to serve only to supply flavor for sugar sirups and use in fine candies and confections. The low saccharine content of the sap, from 2 to 4 per cent of sugar, and high labor cost of manufacture preclude its use in competition on a sugar basis with other sirups.

Maple sirup is made in nearly the same manner as cane sirup, but only early in the spring, most often when there is snow on the ground, and there is more or less freezing and thawing. The sap is caught in buckets at the trees and collected in barrels or a tank dragged about on a sled. It is

TABLE 62.—MAPLE-SUGAR AND SIRUP PRODUCTION BY STATES*

State	Trees tapped, 1,000			Sugar made, 1,000 lb.			Sirup made, 1,000 gal.		
	Average 1927–1931	1933	1934	Average 1927–1931	1933	1934	Average 1927–1931	1933	1934
Maine	254	255	260	19	10	15	37	29	29
New Hampshire	402	388	380	145	46	59	77	50	71
Vermont	5,552	5,290	5,449	1,108	554	678	1,098	625	971
Massachusetts	269	236	236	89	66	105	62	36	65
New York	3,602	3,184	3,216	503	388	284	806	597	668
Pennsylvania	838	664	657	142	108	83	225	209	199
Ohio	1,301	1,216	1,216	50	32	5	367	413	273
Michigan	515	490	436	54	35	13	118	140	72
Wisconsin	263	295	251	10	24	11	70	62	30
Maryland	63	58	57	29	25	18	25	25	17
Total	13,059	12,076	12,158	2,149	1,288	1,271	2,885	2,186	2,395

* Yearbook of Agriculture, 1935.

strained through heavy flannel into barrels and preferably allowed to settle before being drawn off to boil.

For very small production, as on farms, kettles may be made to serve very well, but when the camp contains more than 200 trees, an evaporator of appropriate size is preferred. These can be of iron or copper heavily tinned, and it is usual to figure that for each square foot of furnace exposure, the evaporation will be about 2 gal. per hour. A small pan, 3 by 8 ft., will therefore have a capacity of from 45 to 50 gal. of sap per hour. Since the sap has such a low sugar content and has to be concentrated at the ratio of from 20:1 to 30:1, the importance of a simple device with considerable capacity is apparent.

The juice is run in at one end of the evaporator in a thin layer of about 1 in. and skimmed promptly on the appearance of scum. No clarification or other treatment is needed if the sap has been kept clean, and the sirup should be free from flocculence. The color is normally somewhat dark.

The sirup is finished when it reaches a density equivalent to 11 lb. per gallon. The boiling temperature is from 217 to 218°F. in most places, but may be slightly less in some of the higher regions. The test may also be made by a Brix hydrometer and should show not less than 65 or 70° at ordinary temperature. A sirup as heavy as 12 lb. per gallon is almost certain to have some sugar separation upon standing, and one below 10 lb. per gallon will sour upon exposure.

Canning and bottling are analogous to that for cane sirup.

Sorghum Sirup

Sorghum belongs to the coarse grasses in the family Andropogoneae and is closely related to sugar cane. Its cultivation dates back to very early times in Western Asia and Northern Africa, and probably to an even earlier period in China and India. The chief use at that time seems to have been for its seeds, as they are similar to millet and were used extensively in the making of flour. Sorghum has been used for many centuries in Southern Europe, but as far as can be ascertained, it was not introduced into this country until 1853.

Sorghum is a large, coarse grass, not so large as the sugar cane, neither does the juice have so high a sugar content, but it is a hardier plant, capable of being grown over a wider area and adapted to a variety of soils and cultural methods. It has a further advantage that it requires only a short season and is grown from seed instead of propagated from nodes from the stalks. It retains its subtropical character as shown by the ease with which it is injured by frost. The culture of sorghum is practically the same as for corn.

An average yield of stalks is between 7 and 8 tons per acre, though under favorable circumstances this may be greatly exceeded. The preferable time for cutting is when the seeds are in the milk or passing into the dry stage. The sugar content of the sap at that time is from 10 to 12.5 per cent; it becomes a little higher as the plant matures, but owing to the dangers from frost the canes are cut a little early. A higher percentage of invert sugar is also present in the less advanced stalks and this is favorable for a sirup which will not crystallize any part of the sugar. The yield will vary from 750 to 1,200 lb. per ton, depending upon the state of the crop and the pressure used in grinding.

Sirup.—The production of sorghum sirup is accomplished with the same kind of equipment and of practically the same size as is used for

sugar cane. The 10-ton-per-day unit seems to be most nearly standardized and the larger ones are based upon multiples of this.

Harvesting begins by stripping the leaves and by topping and is followed either by cutting at once or at any convenient time within a few days. Permitting the leaves to remain attached reduces the capacity of the mill and introduces a higher proportion of gummy substances and other matter which interfere with making the best quality of sirup. The maximum yield is obtained by handling promptly in harvesting and through the mill as there are less souring and other changes in the constituents than when delays occur. A necessary step is to filter the juice and allow it to stand for 2 hours or more, as a greater quantity of extraneous material can be separated at this stage than after boiling.

As a secondary step in clarification, the juice may be brought near to the boiling point in a tank, the coagulated albuminous matter skimmed off, suspended matters then allowed to settle, and the clear liquid drawn off. Lime or clay is used sometimes to assist in clarification. The lime aids in the event of an acid juice, but it is doubtful whether these agents offer much improvement over heat alone if time is given for settling.

The open evaporator is used almost exclusively and the skimming must be thorough at the start. Mechanical skimmers are attached to some of the cookers and lessen the labor, although they need attention at short intervals. The cooking of the juice needs to be done in a fairly thin layer, preferably not more than 1 to 1½ in. in depth.

The finishing point for sorghum sirup is practically the same as for cane sirup. The boiling temperature at the finish is 224°F., with slight adjustment of a degree or two less for the higher altitudes. The raw juice enters the evaporator testing from 7 to 14°Brix but must test 70° at the finish; therefore the ratio of reduction will vary from 10:1 to 5:1. A gallon of the finished sirup should weigh 11.25 lb.

The canning is the same as described for cane sirup.

HONEY

Honey is the nectar and saccharine exudations of plants gathered, modified, and stored in the comb by honeybees (*Aphis mellifica* and *A. dorsata*), is levorotatory, and contains not more than 25 per cent of water, not more than 0.25 per cent of ash, and not more than 8 per cent of sucrose.

Comb honey is honey contained in the cells of the comb.

Extracted honey is honey which has been separated from the uncrushed comb by centrifugal force or gravity.

Strained honey is honey removed from the crushed comb by straining or other means.[1]

[1] U. S. Dept. Agr., S.R.A.F.D. No. 2, Rev. 4, August, 1933.

Sucrose[1] is the principal constituent of nectar. Much of it is inverted to dextrose and levulose in the honey sac of the bee. In addition to sucrose, invert sugar, water, and ash, honey contains a small quantity of protein, dextrin, and wax, and usually some pollen. Organic acids are also present.

The characteristic flavor of honey is due to its source. Buckwheat honey is dark in color and has a strong flavor. The honey from white clover has a very delicate flavor. Honeys are derived by the bees from such sources as cotton, basswood, orange trees, apple trees, sumac, tupelo, alfalfa, sage, and thyme.

Honeydew honey is dark in color, dextrorotatory, and has an odor resembling molasses. According to the definition of honey, this product is not a honey, for it is not levorotatory.

Favorable climate and the presence of suitable flowering plants govern the regions where honey can be produced efficiently. Severe winters affect the bees and may kill them if not carefully protected. Hives are constructed to protect the bees from the adverse weather conditions and to house the boxes or frames for the honey. To aid the bees, a comb foundation of wax is often placed in each box.

The main adulterants of honey are invert sugar, glucose, and cane sugar. (These constituents can be detected without difficulty.)

The United States production of honey in 1929 was 83 million pounds with a value of some 12 million dollars.

For additional data on sugar see:

Reynolds, P. K., The Story of Cuban Sugar, United Fruit Co.

Sugar Reference Book and Directory, 1934, Palmer Publishing Co.

Spencer and Meade, A Hand-book for Sugar Manufacturers and Their Chemists, John Wiley & Sons, Inc.

Fairrie, Geoffrey, Sugar. Liverpool, 1925.

[1] Leach, A. E., Food Inspection and Analysis, John Wiley & Sons, Inc., New York, 1920.

CHAPTER VIII

MEAT AND MEAT PRODUCTS

MEAT

The production of meat for human consumption is an industry which involves the labor of millions of our people directly or indirectly. In addition to the many thousands of farmers and ranchers who raise and care for the animals during their life, we have other thousands whose efforts are spent in raising forage and feeds. The railroads and their personnel transport immense quantities of live animals and slaughtered products. Employees of the stockyards and packing houses, the workers in refrigeration warehouses which store and handle meats, and the innumerable storemen and local butchers who direct the final products to their ultimate destination are among those who have a part in this industry.

It has been calculated that the per capita meat consumption in the United States is approximately 138 lb. per year, which is estimated as being higher than that of the United Kingdom (124 lb.), Germany (111 lb.), France (94 lb.), and most other European countries, but less than Argentina (281 lb.), New Zealand (212 lb.), Australia (195 lb.) or Canada (161 lb.).[1] Most of the latter countries have a large surplus of cattle and sheep, and are sparsely populated. The per capita consumption of total meats in the United States has shown a lowering trend during the past 30 years, with the consumption of beef becoming somewhat lower and pork apparently increasing in demand. Mutton and lamb have a per capita consumption of approximately 10 per cent of either beef or pork, *viz.*, between 5 and 8 lb. per year.

In comparing the meat consumption of various countries it is interesting to note that Argentina and Australia are the largest beef consumers. The United Kingdom has the closest balance of beef, mutton, and pork and uses by far the largest proportion of mutton. The Germans eat more pork in proportion to other meats than any other country, although the United States and Canada have a higher per capita consumption of pork than has Germany.

During the first decade of the twentieth century and in the period of the great war the United States was a large exporter of meats, particularly of pork and beef. Since 1921, such exports have decreased markedly.

[1] *U. S. Dept. Agr., Dept. Circ.* 241.

Lard, which is an important export product, reached its peak in 1923 when more than a billion pounds were shipped for export trade.

During the period from 1900 to 1907 some 400,000 head of cattle were shipped alive annually to be slaughtered on their arrival, primarily in England. From 100,000 to 400,000 sheep and up to 80,000 hogs were also exported alive during these years. These exports have also been

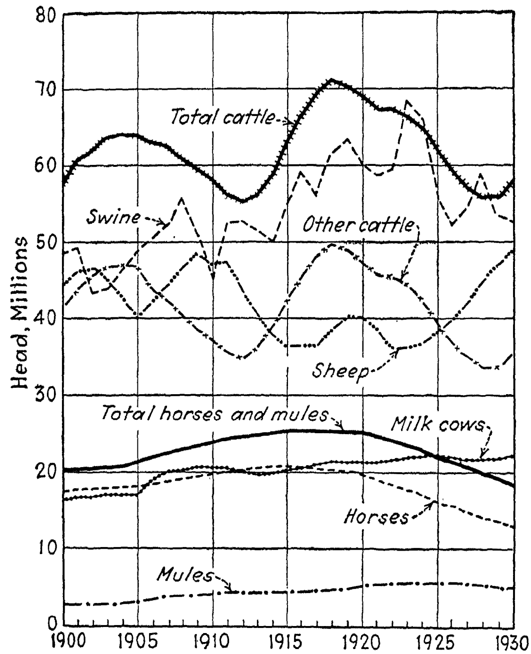


FIG. 21.—The graph suggests that an upward trend in number of cattle, particularly beef cattle, may be expected during the next five or six years, and probably an increasing number of hogs. The feed required by this increasing number of cattle and hogs is likely to more than balance the feed released by the decline in horses and mules, and the gradual recovery in crop acreage since 1924 may be expected, therefore, to continue for several years longer. Most of this increase in crop acreage, however, is likely to occur in the Great Plains region and the Northwest and not in the Southern and Eastern states, where 15,000,000 to 20,000,000 acres of plow land still lie idle. The curves represent estimates by C. L. Harlan, Bureau of Agricultural Economics. (*U. S. Dept. Agr.*)

curtailed to a large extent during the past decade because of competition from other large animal-producing countries, notably Argentina and Australia, which can produce meat at lower cost. Relatively little importation of meat or livestock is done in this country, the live animals usually coming from Canada and Mexico and meat from Argentina.

The above graph, showing the total population of meat and farm animals for the period from 1900 to 1930, allows a general idea of the irregularities of production which have occurred during that time. A considerable increase in production is shown during the first fifth of the

century. Doubtless the varied economic conditions of the past few years and the unfortunate weather conditions which have caused a drought in many cattle-producing areas will change the slopes of these curves for some time to come.

A chart showing the trend of population in this country for the past 80 years, together with the livestock population, enables certain interesting observations. The number of dairy cattle was smaller than the number of beef cattle until 1912, since which time the situation has been reversed, except during the war period, a condition due to increased meat demands. It is apparent that during the past century the great increases

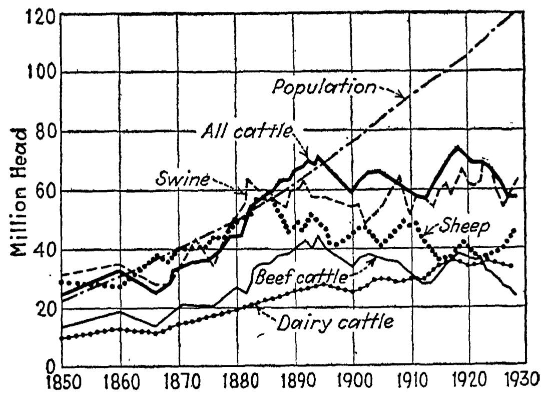


FIG. 22.—Trend of human and livestock population, 1850–1928. (*U. S. Dept. Agr. Circ.* 241.)

in population were concurrently matched by increases in meat animals until 1885 when the sheep population dropped off in rate of increase, followed in the same respect by swine in 1892 and cattle in 1895.

The extent of international trade in meats may be realized from Table 63 taken from Ostertag-Young, showing Great Britain's meat imports which are made possible in part by her own fleet of over 300 vessels equipped with refrigeration systems.

Some idea of the amount of refrigerated space necessary for this vast transoceanic transportation of Britain's food may be gained by a statement of Sir Frank Smith, Secretary of the Department of Scientific and Industrial Research of Great Britain. In 1934 he stated that the transportation of England's food supplies required refrigerated space in ships equivalent to a floating warehouse 20 ft. high, 50 ft. wide, and 20 miles long.

The character of animals used for food production has been greatly modified in recent years. Many more pure-bred animals are now raised than was the case in previous years. In the United States, the State of Iowa leads in respect to pure-bred cattle and swine. The desirability

of maintaining animals of definite pure breeding has become more widely recognized. Likewise, the selection of cattle of breeds with favorable

TABLE 63.—MEAT IMPORTS OF GREAT BRITAIN, 1932*
(Hundreds of pounds)

Source	Beef	Mutton and lamb	Pork	Bacon
Argentina	7,462,063	1,385,720	108,934	
Australia	957,589	1,156,034		
Brazil	481,090			
Canada	....	....	....	182,683
Denmark	....	....	....	7,672,030
Netherlands	....	....	....	971,567
New Zealand	578,881	3,915,865	131,142	
Poland	....	....	....	1,142,524
Sweden	....	....	....	430,248
United States	47,466	....	32,542	63,318
Uruguay	699,849	163,690		

* YOUNG, Ostertag's Textbook of Meat Inspection, taken from Board of Trade Returns, Bailliere, Tindall and Cox, London, 1934.

growth characteristics has proved economically sound from the standpoint of returns when the animals are slaughtered.

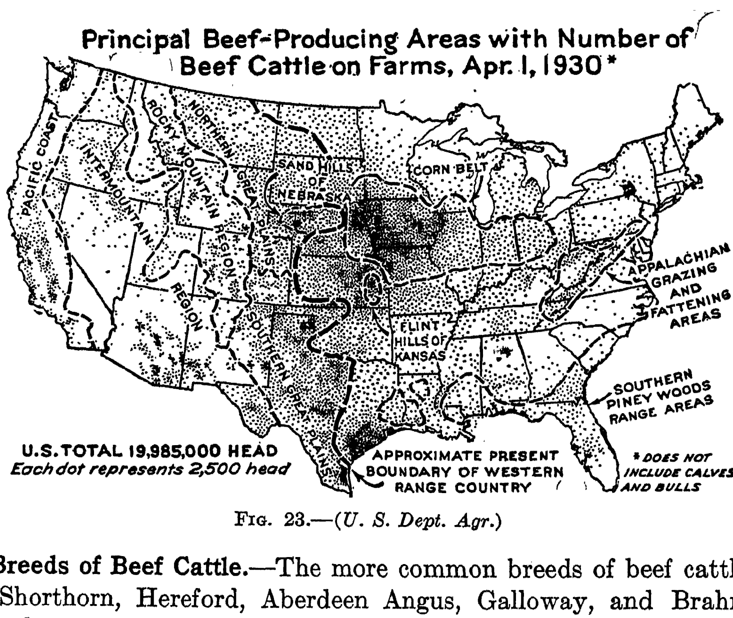


FIG. 23.—(*U. S. Dept. Agr.*)

Breeds of Beef Cattle.—The more common breeds of beef cattle are the Shorthorn, Hereford, Aberdeen Angus, Galloway, and Brahman.[1] These breeds differ from dairy-cattle breeds in that they have been bred

[1] *U. S. Dept. Agr. Farmers' Bull.*, 612, 1930.

selectively to produce meat rather than milk; the cows, except for the Shorthorns, usually have only about enough milk for their calves.

The Shorthorn cattle are most extensively raised. There are both horned and "Polled" or hornless Shorthorn breeds, which differ principally in respect to horns but otherwise are very similar. They vary in color from red to white.

The Hereford and Polled Herefords are second in numbers in this country. Their color is a rich red with a white head, breast, belly, switch, and lower legs. They are said to be able to thrive well even under adverse conditions, a valuable characteristic in any animal.

The Aberdeen Angus is a black-colored breed which has no horns. They are said to be able to stand extremes of heat better than most breeds and have the important characteristic of having a high "dressing-out" percentage, *i.e.*, lower wastage.

The Galloway is usually hornless, black or brownish in color, and smaller than animals of those breeds previously mentioned. It requires a longer period of time for maturation, also.

The Brahman is the name designated for all breeds of Indian cattle originally imported from India. These animals are more common in the southern states as they are noted for their hardiness in resisting insect and other pests and for their adaptation to warmer climatic conditions.

In addition to those breeds mentioned above there are some which are dual-purpose breeds. Of these, the so-called Milking Shorthorn is the most numerous and differs only in body conformation from the beef-bred Shorthorns, as they are all of the same registry. The Red-polled cattle are also popular as a dual-purpose breed and are desirable both as beef producers and for milk yield. The Devon breed steers are used for beef, or sometimes as work oxen, and the cows are fair milk producers. Meat is also obtained from the crosses of numerous less well known types and from the strictly dairy-cattle breeds. The calves which are not to be raised to maturity make a part of our veal supply, and the cows and bulls from Jersey, Guernsey, Holstein, and other dairy breeds are slaughtered for foods when they have outlived their productivity.

Breeds of Swine.—The breeds of swine may be divided into rather distinct classes depending on whether they are being raised primarily for lard or bacon. The more important breeds which are included in the so-called lard types of hogs are the Duroc-Jersey, Poland China, Chester White, Berkshire, Hampshire, and Spotted Poland China. The bacon-type breeds, which are not raised in the United States in large numbers, are exemplified by the Tamworth and Yorkshire breeds. These hogs are longer in body than the lard breeds and therefore make larger quantities of bacon, although the hams and shoulders are proportionally smaller.

The minor breeds of hogs include the following: Mule-foot, Kentucky Red Berkshire, Cheshire, Essex, Victoria, and Large Black.

No one breed of swine is sufficiently outstanding to be considered best for any purpose. There are certain breeds favored in different areas, which doubtless is due to the fact that under local conditions that breed is advantageous from the standpoint of the raiser.

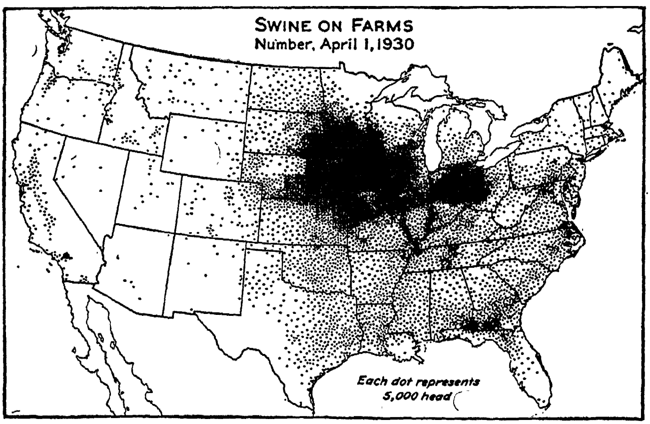


FIG. 24.—(*U. S. Dept. Agr.*)

Sheep Breeds.—Sheep have been bred and utilized for both their meat and wool for many centuries, in fact, since long previous to the Christian era as is attested by numerous Biblical references. Numerous factors have influenced the development of various breeds, such as adaptability to climate, elevation, types of pasturage, and the productivity of the animals for wool, meat, and milk. The number of existent breeds of sheep is greater than that of our other important domestic food animals and the origin of most of the present sheep breeds appears to have been in the British Isles.

Since 1793, when the first Spanish Merino sheep were imported at Boston, some 30 breeds have been introduced, although only about a dozen have attained prominence. No typically American breeds, with the possible exception of the Merinos, have become outstanding in importance.

Many factors are involved in the selection of the proper breed, depending on the location where they are to be raised and the market for which they are intended. There are wide variations in suitability of various breeds for contrasting environments, such as mountain or lowland grazing, susceptibility to heat or cold, dryness, and humidity, etc. A wide divergence is apparent in breeding qualities, breeding habits which determine the time of lambing, efficiency as meat producers, length, quality and quantity of fleece, all of which are important, dependent on the purposes

for which the animals are raised. Some of the characteristics of the better known breeds are outlined below.

Southdown—The best mutton breed. Small in stature, active in habit. Thrive well in hilly pastures. Their fleece is short and quite fine, hence light in weight.

Hampshire—One of the largest of the mutton breeds. Owing to their size these animals are less adapted to rough, scanty pasturage. When well fed, the lambs develop very fast and arrive at market size quickly. The fleece is coarse and close.

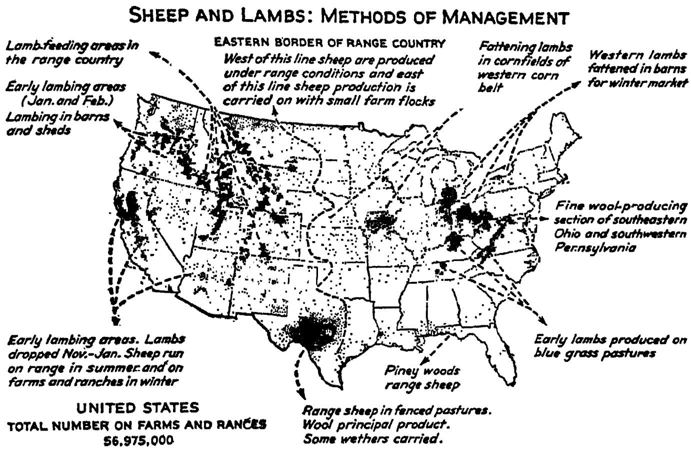


FIG. 25.—(*U. S. Dept. Agr.*)

Shropshire—A good dual-purpose breed. The lambs are somewhat slower in developing. Require rich pasturage.

Oxford—Large, heavy animals. Not suited for ranges, but ideal for mixed farming where rich food is available for rapid development. Fleece of medium fineness and good weight.

Dorset—Medium stature. Used mainly for mutton where winter or hot-house lambs are wanted. Breeding habits permit lambing in the fall. These animals may be bred twice a year. Fleece is coarse and medium in weight.

Cheviot—A good dual-purpose breed for rough, scanty pasture. Fleece is thick, long, and medium fine.

Cotswold—Biggest of the mutton breeds. Suited for low moist pastures and adapted to damp climates. Lambs develop slowly. Fleece long, coarse, and of good weight.

Lincoln—Good, medium-sized mutton animals. Similar to Cotswold in habit. Fleece is coarse, long, and heavy.

Merino—Essentially a wool breed. Fleece very fine and long. Ideal range breed. Can stand sustained travel for food and water. Resistant to disease and parasites.

Rambouillet—Primarily a wool breed, but have been developed to produce fair mutton. Adapted to ranges. Fleece fine and long.

TABLE 64.—ANIMALS SLAUGHTERED FOR FOOD IN THE UNITED STATES DURING 1931

State	Number	Cost on hoof, $	Weight on hoof, lb.	Weight, dressed, lb.
		Cattle		
Illinois	1,768,594	112,116,079	1,719,855,102	947,342,548
Nebraska	873,131	59,082,810	854,522,054	485,084,449
Kansas	834,944	47,570,895	763,464,391	421,279,838
Iowa	686,510	42,546,726	640,252,963	355,563,992
California	621,829	37,083,225	612,862,654	331,920,374
New York	515,326	45,339,772	566,932,736	317,946,710
Minnesota	543,961	26,338,430	516,770,009	270,684,325
United States	9,308,270	552,383,958	8,785,381 299	4,788,555,300
		Hogs		
Illinois	8,226,568	132,859,832	,045,684,685	1,513,754,908
Iowa	5,620,763	91,034,248	,414,602,131	1,064,078,585
Minnesota	3,917,731	60,106,454	953,583,966	707,958,086
Kansas	2,999,786	47,052,015	721,370,432	530,911,616
Nebraska	2,654,291	44,843,637	714,050,302	529,314,337
Ohio	3,069,856	46,707,987	691,624,051	513,595,361
Missouri	2,917,536	40,776,696	641,595,839	477,487,552
United States	49,425,477	749,343,286	11,317,684,790	8,365,308,335
		Sheep and lambs		
Illinois	3,350,047	19,870,892	274,538,579	130,560,837
New York	3,150,496	23,408,046	275,220,258	126,071,981
California	2,268,785	12,128,068	176,186,437	86,319,016
Nebraska	1,941,646	11,938,786	162,656,492	77,989,505
Kansas	1,566,371	8,769,508	127,675,173	60,037,098
Missouri	1,312,667	7,788,772	107,814,895	51,600,094
United States	20,445,037	119,764,891	1,644,315,664	778,538,735

Inspection.—The inspection of all animals slaughtered in the United States, the products of which are to enter interstate or foreign trade, has been required by law since 1906. It is estimated that about two-thirds of all animals slaughtered undergo this inspection, the other third being slaughtered in states where the products are consumed locally.

The work is under the direction of the U. S. Department of Agriculture, Bureau of Animal Industry, and was first inaugurated because of an embargo placed on American hog and beef products by several European countries, including Italy, Germany, France, and England, supposedly because of certain diseases. The Bureau of Animal Industry was established in 1884 to obtain and publish information concerning the cause, treatment, prevention, control, and eradication of animal diseases. In 1890 and 1891 Congress passed legislation authorizing regulations concerning the ante-mortem and post-mortem inspection of cattle, and particularly the microscopic examination of pork for trichinosis, which was the disease primarily responsible for the embargos mentioned above. This enabled those products which were passed to be certified, and in a short time the embargo was lifted. In 1894 and 1895 the service was extended to include ante-mortem and post-mortem inspection of hogs, calves, and sheep, although these products did not generally enter the export trade. In the latter year authority was granted by Congress to destroy condemned meat products, which hitherto was not possible. The service was gradually extended in scope and eventually came to embrace all sanitary conditions which are concerned with the packing industry.

The meat-inspection act of June 30, 1906, gave added powers and duties to this bureau. It provided that all cattle, sheep, goats, and hogs should be subject to both ante-mortem and post-mortem inspections when they are to enter interstate or foreign shipment and provided for stamps, "U. S. Inspected and Passed" for foods which meet the proper requirements. The power was also granted to destroy all food products containing dyes, chemicals, or ingredients which render the meat unfit for food and to maintain proper standards of sanitation in the buildings used for slaughter. Penalties to be imposed for the breaking of the various parts of these regulations were also established.[1]

Definite rules and regulations are set up for the ante-mortem inspection of food animals which is generally carried out by veterinarians. The presence of such diseases as anthrax, black-leg, rinderpest, tuberculosis, rabies, glanders, septicemia, splenic fever, or tetanus may require condemnation and disposal. Animals having such diseases may be ordered killed without entering the edible foods establishment. Tentative rejection may be made of animals suspected to be infected or which have been in contact with other animals having certain communicable diseases, and such animals are isolated under observation. They may be labeled "U. S. Suspect" and killed separately, in which case the post-

[1] For a complete citation of the Meat Inspection Law and a discussion of many phases of this work, see Meat Hygiene, by EDELMAN, MOHLER, and EICHHORN. Lea & Febiger, Philadelphia.

mortem inspection will confirm previous decisions and condemn the carcass to the inedible division, or on the other hand, the tag may then be removed and the meat passed if found satisfactory. Animals injured in transit, heated, or fatigued may be ordered to rest for some definite period before slaughter.

Those establishments which have government inspection are under very strict regulations concerning sanitation. The construction of the plant with respect to drainage, plumbing, drains, gutters, etc., must meet with definite requirements. The water supply must not only be pure and potable, but in adequate quantity. Separate parts of the establishment must be maintained for handling edible and inedible products. All floors, walls, etc., must be of such construction that thorough cleaning is possible. Adequate toilet and hand-washing facilities must be available. Means for disinfecting and cleaning utensils must be provided. Sterilizing equipment is required for implements used in handling carcasses or parts found to be diseased. Containers and tank cars must be examined before using for edible products. The operations in the plant and the conduct or personal habits of employees must be guarded carefully to maintain strict sanitary procedures. No fly or rodent nuisances are tolerated and everything possible is done to ensure the purity of the products which, if passed by the inspectors, are so stamped. This is done with ink in such a manner that the number of the establishment is also marked, should it be necessary to know where the inspection was made.

In addition to eliminating diseased or otherwise unfit meat from the general food supply and supervising the preparation of meats and meat products, the Federal inspection guards against the use of harmful dyes, preservatives, chemicals, and other ingredients, and prevents the use of misleading names or statements on labels.

Nearly 800 establishments located in 250 cities and towns, were under Federal inspection in 1933, and in these establishments over 70 million cattle, sheep, and hogs were slaughtered that year. The average cost per animal inspected was only 7.3 cts., according to Baumann[1] of the U. S. Bureau of Animal Industry.

Slaughter of Cattle.—The animals to be slaughtered are driven into pens holding only a few animals so that they are crowded and movement is restricted. From these pens they pass through a narrow passage to the killing room. In some cases the animals are stunned or "knocked" by hitting them on the forehead with a round-headed sledge hammer. This procedure, if used by experienced employees, should render the animal unconscious immediately. In Europe and Great Britain numerous devices are available whereby the stunning may be accomplished by

[1] Baumann, E. H., *New Jersey Pub. Health News*, June, 1934.

bullets from special guns or mechanical bolt contrivances which are considered more humane. An electrical means whereby a high-voltage current is passed through the animal's head from behind the ears has attained some usage in England recently. In the United States the hammer is widely used, except for those animals destined for the kosher or orthodox Jewish trade, which because of religious custom must not be stunned.

When the stunning is completed a short shackling chain is attached to the hind leg or legs and the animal hoisted so the head hangs a short distance above the killing floor where it is "stuck" or bled. An incision is made in the skin of the neck anterior to the sternum through which the jugular veins may be reached and severed. If the kosher method is used, the animal is hoisted up by a chain around one hind leg until the weight of the body is well off the floor, then a muzzle device is applied to the head of the animal and the head pulled back to leave the ventral portion of the neck clear for the long knife of the Jewish official who cuts the throat posterior to the jaw.

Regardless of what killing method is used, it is essential that the animal be bled as completely and as rapidly as possible, because the quality of the final products is dependent on this.

If the blood is to be used for food purposes, the neck of the animal, the knife, and the hands of the workman should be thoroughly cleaned before the cutting is done and the blood should be caught in a sterilized vessel which is marked with a number identical with the animal so that the blood may be rejected if the carcass is rejected by the inspector at the time of his examination. If it is "passed" by the veterinarian, the blood may be used as such in food materials or subjected to further treatment and used for the manufacture of dried blood albumen.

Butchering of Cattle.—When the animal has been completely bled, the skinning operations are started. The carcass is still suspended by one leg from an overhead rail when the hide is skinned from the head, the head unjointed and removed immediately after the esophagus is severed. Care must be taken to prevent contamination by paunch contents and each head must be numbered for identification by the inspection force, which subsequently examines it for lesions.

The carcass is lowered to the floor, propped by pritch poles, and the skinning operations continued. The dew claws are removed, the feet skinned, the legs disjointed at the knees or hocks, and a ventral incision made the length of the median line. The esophagus is separated from the trachea, then tied to hold in the paunch contents and pulled into the body cavity. The genital organs are removed and the hide carefully cut from the body and legs. The last of the hide is removed after the carcass is again raised off the floor.

The evisceration must be carefully carried out to keep bacterial contamination at a minimum. The openings of the alimentary canal and bladder are tied before the visceral organs are cut and pulled loose and then dropped into viscera trucks or placed on special inspection tables. Here the government veterinarians make a part of their examinations, after which the various organs are dispatched to other departments where they may be separated, cleaned and further designated as fresh foods, material for rendering, by-products, or otherwise.

After the final inspection of the carcass is made, it is split longitudinally in two halves, trimmed, external blood vessels removed, the

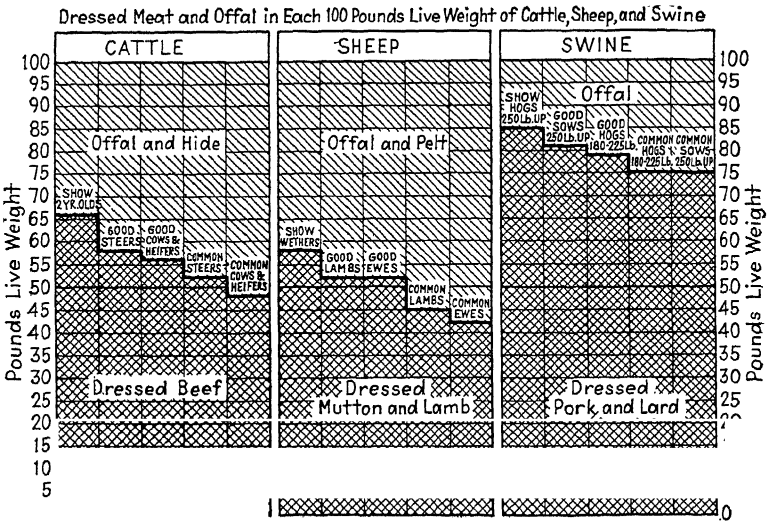


FIG. 26.—Average dressing percentages of cattle, sheep, and swine, showing the superiority, from a meat standpoint, of well-bred livestock. (*U. S. Dept. Agr. Circ.* 241.)

tail and cord removed, and the inside thoroughly scrubbed and cleaned with brushes and spray jets. The better-grade carcasses are often covered or shrouded in heavy cloths which are tightly wrapped and pinned about the still warm exterior in order to present a more attractive appearance after chilling which immediately follows. The cloths are later removed. Before going into the chill room, the halves are usually weighed.[1]

The percentage weight of the dressed-out carcass depends on a number of factors which include breed, type, quality, size, condition of the animal at the time of slaughter, sex, and care in trimming operations. Average steers generally dress out a little above 50 per cent, whereas choice animals may run to 60 per cent and some others higher. Very poor grade "can-

[1] See EAKINS, Military Meat and Dairy Hygiene, Williams & Wilkins, Baltimore, for a more detailed account of slaughtering operations.

ner" cattle (those only fit for canned meat products) may dress much lower. Figure 26 indicates the comparative dressing percentage of various meat animals.

Slaughter of Hogs.—The handling of hogs at the slaughterhouses differs somewhat from that of cattle in that they are not generally stunned before sticking. The animals are crowded into pens in order to limit their activities, a shackle chain is attached around one hind leg just above the hock, and by means of a large vertical wheel the animal is hoisted from the floor to an overhead conveyor which carries the animal to the sticker. This operator makes a median incision anterior to the sternum and thrusts the knife toward the heart so that an incision about 3 in. long is made which successfully severs the blood vessels so that bleeding operation will be completed within a few minutes. The skill with which this operation is conducted determines in part the quality of the product, because poor or incomplete bleeding damages the quality of the meat and requires excessive trimming. After the animal is thoroughly bled the carcass is conducted along the overhead rail and dropped into a scalding vat containing water at a temperature slightly below 150°F. The scalding water is usually made alkaline with sal soda in order to facilitate the cleaning process, and it assists in loosening the bristles. This tank, or vat, which is sometimes 40 ft. in length, has a mechanical conveyor which moves the hogs along slowly through the tank, being operated at such a speed that each animal will be submerged for 3 or 4 minutes. Care must be taken to prevent the animals from remaining an undue time in the tank or having the water too hot, because under such circumstances the fat in the animal may be slightly melted and spoil its appearance. Immediately after they are removed from the tank, the carcasses are shackled beneath the tendons of the hind leg and conveyed through a dehairing machine which removes the majority of the hair and scurf. Further dehairing and scraping are necessary which is accomplished by hand or by the use of gas torches in the hands of especially trained operators. The legs are separated by means of gambrel sticks and the carcasses hung on an overhead rail conveyor. The dew claws and toes are pulled off, the hair around the eyes and ears removed by a gas torch, and the nares cleaned with a steam jet, after which the head is disarticulated and nearly severed from the body thereby enabling a rapid examination of the cervical lymph nodes by the government inspector. The carcass is slit open and the evisceration process carried out. The viscera are usually placed on separate trays which are mechanically actuated so that the tray progresses side by side with the carcass from which these organs have been removed; this facilitates inspection and identification in case it is necessary for either or both portions to be condemned by the veterinarian who carries out these inspections. Such

trays are usually a part of an endless belt which is subjected to sterilization by means of live steam in the interim before being used as a container for materials from another animal. As the carcass progresses along the rail, the other organs are removed. The animal is eventually split and after the inspection has been completed, if passed, the carcass is cleaned and branded and transferred to the cooler room where weighing operations are completed. The dressing percentages of high-quality hogs and sows, after the head is removed and the leaf lard taken out, run in the vicinity of 80 per cent of the total weight.

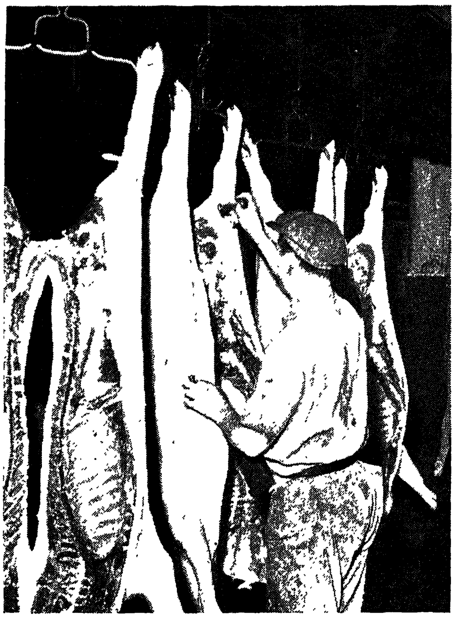


FIG. 27.—Inspection of hog carcasses. (*Food Industries.*)

Slaughter of Sheep.—In many of the large slaughtering establishments the sheep are led from their pens to the killing floor by a goat trained as a leader. When they arrive at the special pen the sheep are shackled by one hind leg and elevated to an overhead conveyor rail by means of a large wheel. They progress along this conveyor to a point where they are stuck and bled to death by a sharp knife cut, posterior to the right jaw. When bleeding is completed, the feet and lower legs are removed, the face cut off, and the neck skinned. From an opening made in the neck the esophagus is tied, and then the pelt is cut in the median ventral line the whole length of the body. Starting from this cut, the pelt is separated from the carcass by careful use of a knife and the manual efforts of the operator in order that neither the pelt nor the connective tissue, the

"fell" adjacent to it, is injured. The carcass is next washed thoroughly. Before the viscera are removed, the rectum is loosened and dropped into the pelvic cavity and the esophagus ligated. The viscera are placed on pans which are identified so that the inspector may tell which animal they came from if rejections are necessary. The genital organs are discarded. The sternum is split in the center and the pluck removed. The interior of the animal is thoroughly cleaned and if it has been passed by the inspector, is ready for the chill room.

With some of the better grades the back is broken and spread by sticks and covered with caul fat from the same animal in order to give the carcass a more attractive appearance. This is termed "caul dressing."

The average dressing yield of sheep is about 50 per cent, with lambs running somewhat higher, and old ewes lower than the above figure.

Post-mortem Inspections.—In the post-mortem examination of cattle, hogs, and sheep there are certain localized lesions which may require only the rejection of parts of animals. In these instances such parts are stamped "U. S. Inspected and Condemned" and are immediately placed in trucks or containers so labeled and conveyed to the "inedible" division of the slaughterhouse or kept under the custody and supervision of the government inspectors. Some parts which are capable of use for foods only after sterilization are labeled "Passed for Sterilization" and kept under supervision until they have been sterilized according to regulations. All the diseases of animals which require action by inspectors and the extent to which such diseases must be present in order to be subject to various actions, such as condemnation, rejection, sterilization, etc., are the particular concern of the veterinarian and will not be here discussed.[1] Among such diseases, however, are several which are of particular interest because of means by which the safety of the consumer of products so infected may be guarded by diversified methods.

One of the most serious diseases in food animals is tuberculosis. Very serious efforts have been made to eradicate this disease in dairy cattle. These are discussed in the section relating to milk supplies. Tuberculosis is prevalent in meat animals also, particularly in cattle and hogs. Several tuberculin tests have been perfected which are accurate in determining the presence of the disease, when carried out by properly trained persons. The disease may be localized in definite organs and under such conditions it is sometimes necessary for inspectors to condemn only the organs affected in order to obviate any danger from the standpoint of the health of the consumer. In 1930, there were some 8 million cattle slaughtered under Federal supervision and of these, over 222,000

[1] *a.* Edelman, Mohler, and Eichorn, Meat Hygiene. Lea & Febiger, Philadelphia.

b. Martin, C. R. A., Practical Food Inspection. Lewis & Co., Ltd., London.

were "retained" on account of tuberculosis, meaning some part of the carcass was infected and over 26,000 were "condemned" for the same reason. Of about 46 million hogs slaughtered in the same year, over 5 million were "retained" and 42,000 "condemned" because of tuberculosis. As only about two-thirds of our meat is inspected under Federal inspection, and considering the fact that it is not unlikely that some small slaughtering establishments not under the rigid inspection regulations may have higher percentages of poor cattle, it is apparent that the menace of tuberculosis is one of great seriousness from the standpoint of both health and economics. The elimination of this disease can be accomplished and should be carried out in as short a time as possible.[1]

Trichinosis, a disease in hogs caused by Trichinae, was determined in the early days of meat inspection by microscopic methods which have since been eliminated in this country. The causative organism, *Trichinella spiralis*, is a roundworm that may be found in the intestines of man, swine, rats, and other animals. The fertilized females penetrate the glandular tissues of the intestinal tract and the embryos gain entrance to the blood stream. They settle in the striated or voluntary muscle tissues, injure the contractile elements of the muscle, and eventually become encapsulated within the muscle sheath. These capsules are later calcified by an outer layer of lime salts. The ingestion by another individual of such muscles containing living Trichinae, which at that time are in an asexual stage, will result in the development of mature worms in the intestine and start the cycle in the new individual. Proper cooking eliminates danger from the organisms. When pork products which may be eaten raw are treated by being refrigerated for 20 days at temperatures lower than 5°F., they are also made safe if Trichinae are present. By the use of specified curing operations, in which the percentage of salt, the temperature, and length of smoking or drying operations are definitely set for different products, the transmission of trichinosis is also prevented. The usual methods used in quick-freezing are such as to kill these organisms. Such treatments are not necessary if by the use of heat, all portions of the meat reach a temperature of 137°F., which is lethal to Trichinae.

Both beef and pork are subject to a condition known as measles, due to the larvae of tapeworms. That in beef is caused by *Cysticercus bovis* which is an asexual stage of *Taenia saginata*, a tapeworm which may develop to the length of 20 ft. in the intestine of a person who ingests such infected raw meat. The use of heat in cooking such meat, freezing, or refrigerating for a period of three weeks is usually sufficient to kill such

[1] For a discussion of the Detection, Control and Eradication of Tuberculosis in Livestock, see KIERNAN and WIGHT, *U. S. Dept. Agr. Farmers' Bull.* No. 1069, 1930.

organisms. The organism causing measly pork is *Cysticercus cellulosae* and is the larva of *Taenia solium*. It may be found in the heart muscle and various other muscle tissues. At present this disease is rather rare in this country, but when present the causative organisms may be killed by heating the pork until it is all turned to a gray color, by pickling in salt brine for several weeks, or by freezing to subzero temperatures for several days.

Cooling.—After the various carcasses have been passed by the inspectors, it is essential that they be cooled within as short a period of time as possible in order to prevent changes due to microorganisms and enzymes. In the past it was a common belief that unless the carcasses were allowed to cool slowly at room temperature, the animal heat, which was assumed to be of a distinctly different character from other high temperatures, could not be properly dissipated and spoilage would result. The packing industry, like its companion, the dairy industry, has learned that heat is heat regardless of its origin and the changes due to bacteria and enzymes go on at elevated temperatures just as well in meats when they are warm due to the fact that they were recently parts of living animals as would be the case if these products were in incubators maintained at the same temperatures by electricity, gas, or steam. To prevent these changes, immediate chilling is necessary.

The size of the pieces to be cooled, as well as the temperature of the chilling room, will determine in part the length of time necessary for the entire product to be cooled. The larger the pieces, the longer the time which will be required to get the interior portions of the meat to lowered temperatures which will not favor bacterial reproduction and spoilage.

The temperature as well as the humidity of the storage room is of importance in governing the types of microorganisms which will develop on or in the meat. With low humidities there is a partial dehydration of the exterior surfaces which tends to lower the incidence of bacteria and molds. Excessive drying is not desirable from the standpoint of the packer because it causes greater shrinkage in the weight of meat. High humidities favor the growth of bacteria on the surface and likewise provide conditions conducive to mold development. In addition, changes which are undesirable occur in the color of the tissues and bad odors may develop. These growths of microorganisms, which tend to penetrate more deeply into the tissues with the passage of time, progress fairly rapidly at ordinary room temperatures but are checked to a marked extent by temperatures near or below freezing. In recognition of this fact some meats are frozen, especially those which are exported, but the greater part of our meats are "chilled" promptly, *i.e.*, brought to temperatures slightly above freezing, and maintained at such temperature

levels until used. Regardless of the size of the carcass or cut of meat the chilling should be so controlled that these levels are reached within 24 hours.

Meat cannot be kept indefinitely at temperatures of chilling without undergoing changes which will eventually result in products unfit for foods. Autolytic enzymes normally present in meat and the enzymes elaborated by bacteria and molds will eventually hydrolize or chemically split the proteins of the tissues into simpler chemical compounds. The fatty tissues are subject to the attack of the lipases or fat-splitting enzymes which chemically separate fats into glycerol and fatty acids through their catalytic activities. Such incipient chemical changes, especially of the proteolytic enzymes, if allowed to extend only for relatively short periods of time, 2 to 6 weeks at chill room temperatures, may be beneficial in "tendering" the meat and producing flavors which are desired by certain consumers but, if continued, the eventual result is putrefaction and decomposition. If meats are to be kept for longer periods, they should be frozen.

The bacteria and molds which occur in or on properly inspected meat handled under sanitary conditions are not microorganisms which are dangerous to health, except in very rare instances. Their activities are of importance primarily because of putrefaction and the lowering of the appearance of the product. Surface growths of molds which develop in cold storage may be wiped off in some cases, or trimmed off with a knife, unless their growth and accompanying enzymic action have been extensive enough to cause changes which may affect flavor. Mold growths in general are more prevalent at the temperatures used in meat refrigerators because at higher temperatures bacteria outgrow and restrain the molds. There are numerous types which are likely to be prevalent, including Aspergillus, Penicillium, Mucor, Cladosporium, Sporotrichium, Thamnidium, Alternaria, Monascus, and Monilia. Torulae and yeasts are also found on some meats in refrigeration.[1]

One type of damage due to molds growing on meat is caused by the discoloration due to pigment-producing organisms. As molds are aerobic and thus require free oxygen, their main activities are near the surface where abundant air supply is available, although the mycelium may penetrate to the depth of a few millimeters. Mold infections of meat are the result of contaminations in handling and from the air in the establishment which may contain mold spores. Frequent cleaning of benches, floors, walls, ceilings, etc., is necessary to keep the incidence of molds low and it should be supplemented by the use of chemical solutions of fungicidal and germicidal compounds such as flushes or sprays. Chlo-

[1] G. B. Food Investigation Board, *Special Report* No. 17, Brooks and Hansford.

rine-containing compounds are particularly effective and sodium hypochlorite has attained quite common use in this respect.[1]

Refrigeration and cleanliness are the most satisfactory means of checking the development of bacteria in fresh meats. Chemical preservatives are not used as they are prohibited by law, and such materials are not necessary if adequate care is taken in handling and refrigerating meats. The type of changes which may occur when care is not used is dependent on the bacteria which are present in or on the meat. Sometimes a condition known as souring occurs in beef. This has been reported by Bunyea[2] as due to *Bacillus megatherium*, an aerobic organism producing propionic acid. In hams a characteristic type of spoilage called ham souring or bone souring was found by McBryde[3] to be due to an anaerobic type of bacillus to which he gave the name *B. putrefaciens.* This organism was found to grow along connective-tissue bands between muscle bundles and developed best in deep tissues where oxygen was absent.

Boyer[4] found several species of anaerobic bacteria in sour hams and shoulders, and located some of the same organisms in bone marrow and other tissues, thereby indicating the possible source of such causative organisms in the animal itself. He emphasized the fact that proper refrigeration and cleanliness are of utmost importance and also brought out the importance of time as an element, in that the sooner the carcass was cooled, the better.

Cutting.—When the beef carcasses, halves or quarters, are thoroughly chilled, they may be delivered to wholesalers or dealers in that form. Some of them are usually cut up in the same establishment, however, and only certain portions used for fresh meat shipped away. The remaining parts or cuts may be converted into other food products, salted, smoked, pickled, or canned.

After the hog carcasses have hung in the chill room long enough to reach temperatures of 32 to 34°F. in all parts of the meat, they may be divided into the familiar cuts such as hams, shoulders, loins, bellies, feet, head, bones, fat, etc. The cutting rooms are now often artificially cooled to keep the meats in perfect condition. Many of the cutting operations are at present facilitated by the use of electrically operated saws which speed up the work. Those cuts which are to be sold as fresh pork are graded and returned to refrigerators or sent to the shipping department. The fat portions which are to be rendered are dispatched to the tanks. The hams and shoulders which are to be cured are conveyed to the pickling

[1] Moulton, C. R., Meat through the Microscope, University of Chicago Press.

[2] *J. Agr. Research*, **21**, 689, 1921.

[3] *Am. Food J.*, April, 1923, p. 197.

[4] Boyer, E. A., *J. Agr. Research*, **33**, 761, 1926.

department, and the sides for bacon, to the salting room where they will be cured and later smoked.

Grading.—In recent years attention has been directed toward grading of meats, a practice which had little uniformity among packers until after 1915. In 1927, an official grading and stamping service was inaugurated by the U. S. Department of Agriculture in Chicago, limited at first to two grades Prime and Choice steer and heifer beef. In 1928, it was extended to include a third grade, Good grade steer and heifer beef. Since then there has been added Medium, Common, Cutter and Low Cutter Grades. The grade as well as the class, *i.e.*, steer and heifer, cow, stag, bull, are plainly marked with a stamp at short intervals on each piece so the buyer will know what he is getting. The service was free at

TABLE 65.—MEAT-PACKING PRODUCTS, BY KIND, QUANTITY, AND VALUE FOR THE UNITED STATES, 1929*

Kind of meat	Pounds	Value
Aggregate value	....	$3,434,654,098
Fresh meat		
Total value	....	$1,780,842,559
Beef	4,575,491,960	859,802,873
Veal	511,102,745	107,196,896
Mutton and lamb	601,718,832	145,416,001
Pork	3,571,276,745	603,537,342
Edible organs, tripe, etc	568,686,957	63,029,655
Other fresh meat	16,382,573	1,859,792
Cured meat, total value	....	$ 748,418,116

Packing-house Products, 1929

Beef, pickled and other cured	71,593,184	$ 21,748,985
Pork, pickled and dry-cured, smoked	1,295,187,924	302,925,443
Pork, dry-salted, smoked	101,778,955	20,642,253
Pork, pickled and dry-cured, not smoked	,271,066,105	231,241,113
Pork, dry salted, not smoked	860,147,550	113,887,890
Cooked hams	152,188,917	57,972,432
Canned meat	149,582,361	38,114,158
Canned sausage	19,551,909	4,404,404
Sausage (not canned), meat puddings, head cheese, scrapple, etc.	928,573,434	201,623,004
Sausage casings: total value		21,847,525
Beef casings	42,878,150	8,067,081
Sheep and lamb	25,271,420	5,124,635
Hog	48,212,414	8,655,809

* Fifteenth Census of the United States, 1930. Manufactures 1929, vol. II, p. 176. U. S. Dept. Comm. Bur. Census.

first but is now done on an hourly-charge basis to those packers who desire the services of an expert grader. For the full descriptions of each class and grade of market meats the reader is referred to recent government publications.[1]

Kosher meat is that slaughtered and meeting the requirements of the orthodox Jewish religion as passed by the shohet, or representative of that faith who conducts the necessary rites and inspections. Only fore quarters are used and the kosher meat is stamped with Hebrew symbols which are for its identification by the purchaser. These stamps are not to be confused with U. S. Department of Agriculture stamps which have nothing to do with this type of inspection, although very often kosher meat also undergoes U. S. inspection. As kosher meat is supposed to be sold within three days of slaughter, unless it goes through further rites, much of such meat must be killed near the consumers. Beef and veal are the most important kosher meats.

Other Products from Meat Animals.—In addition to the dressed meat comprising the carcasses of the three major meat animals, cattle, hogs, and sheep, there are various other parts which are used as foods, sometimes in their original fresh form, but more frequently modified in some respects. These additional products are among those which have made the large packing house of today a means of conservation of many parts of the animals which in a small rural slaughtering establishment would be discarded for lack of facilities to handle such small quantities of each material in an economic manner. A few of these products are mentioned below.

The hearts of cattle are often sold in a fresh state after passing inspection to ensure the absence of measles, which requires both auricles and ventricles to be cut open. If they are to be kept any length of time, hearts should be thoroughly washed, chilled, and sometimes frozen. Those not used in the fresh state, together with hearts of sheep, hogs, and calves, may be used in making sausage or other products of that nature.

The livers of cattle and hogs are used as foods and in recent years have been in much greater demand because of their therapeutic value in conditions of anemia. Calves' liver, which is said to be most effective for this purpose, has sold sometimes at a price exceeding 75 cts. a pound in Eastern markets. If they are to be kept more than a few days it is common practice to freeze livers. Livers require very careful inspection

[1] Beef Grading and Stamping, *U. S. Dept. Agr. Leaflet* 67.
Pork and Pork Cuts, *U. S. Dept. Agr. Circ.* 288, 1933.
Beef, *U. S. Dept. Agr. Circ.* 208, 1932.
Veal and Calf Carcasses, *U. S. Dept. Agr. Circ.* 103, 1930.
Lamb and Mutton, S.R.A. No. 123. U. S. Dept. Agr. Bur. Agr. Econ., 1931.

as they are the site of lesions of numerous diseases and may also be infected with flukes and other parasites. Sheep livers are not usually sold in the fresh form. Livers from all animals may also be used in products such as liver sausage, liver pudding, and other products of that nature.

The kidneys of cattle and sheep are usually sold as a part of the carcass. Those from hogs, as well as kidneys from cattle which are not disposed of with the carcasses, are sometimes used in some canned stews and other products.

The stomachs are emptied, cleaned, trimmed, and may be used in part for tripe. The paunch, rumen, or first stomach of cattle makes plain tripe. Honeycomb tripe, which is so named because of its characteristic appearance, comes from the second stomach or reticulum. After thorough washing the tripe is boiled several hours, then chilled, and later pickled in a sodium chloride and sodium nitrate brine. The final process is packing in grain vinegar to make it acid. Some tripe is now canned. That not pickled may be used in the manufacture of sausage.

Brains are used in the fresh form or may be frozen. Those which have been bruised in slaughtering operations may be used in canned products.

The tails from beef are marketed in the fresh or frozen form or may be used for soups and canned products.

The forefeet of pigs, after careful trimming and cleaning are pickled in brine for two or three weeks, later boiled for several hours, and packed in spiced vinegar. This product, known as pickled pigs' feet may be sold in bulk or canned. The hind feet are more often rendered or used as glue stock.

The sweetbread or thymus gland of calves and young cattle, which is located in the thoracic cavity, is sometimes sold as such in the fresh form or frozen.

The fries, or testes, of male animals are sometimes sold as such for food.

Pig skin, aside from its use as leather, may be used for making jelly stock for canned meats or sometimes serves as a raw material for high-grade edible gelatin.

Blood which has been collected under carefully controlled aseptic conditions from inspected animals may be used in blood sausage and similar products, or it may be made into blood albumin. For the latter purpose the blood is defibrinated by stirring with a clean sterilized rod and later subjected to chemical treatment and a final dehydration process which leaves a dry almost colorless powder which may be used in place of egg albumen for baking purposes. It may also be used as an adhesive.

The intestines and some other tissues of meat animals may also be used for casings for edible foods after proper cleaning and treatment.

Bladders, weasands (which are the inner linings of the esophagus), large and small intestines, and even the rectum of the smaller animals, may be used. The weasands and bladders are thoroughly cleaned, then inflated like balloons, tied, and allowed to dry. The various intestines are trimmed, stripped of intestinal contents, any adhering fat removed, turned inside out, and the mucous slime removed and then washed and further cleaned by hand. Some of these casings undergo a fermentation process which facilitates the removal of slime. Some casings are also packed in salt at some stage in the process. They are used for bologna, frankfurters, liverwurst, ordinary sausage, and similar products dependent on size and shape.

In the past few years a competitor to these casings for holding meat products such as frankfurters and bologna has appeared. The use of transparent cellulose wrappings has already gained some headway in this field and such materials have some obvious advantages from the standpoint of visibility and possibly from that of aesthetics.

Many glandular products, including pepsin, trypsin, rennin, pancreatin, pituitary hormones, adrenalin, thyroid, and parathyroid extracts, and the male and female glandular substances are also obtained from the special organs of slaughtered animals for the manufacture of enzymes, hormones, and pharmaceutical preparations of varied types.

OLEO STOCK

Oleo stock is prepared from beef fat. Some of the fats employed are the caul and ruffle fats, the fat from the rennet, paunch, heart, liver, and pluck. Oleo oil and stearin are derived from oleo stock.

Fats are carried from the slaughtering floor directly to a fat cutter, where the large pieces are sliced in order that they may be cooled quickly. From the cutting machine the fats go to a washing vat, which performs the dual purpose of washing and chilling. The water in the vat is maintained below 40°F. Following washing, the fats are placed in cooling vats for a period of at least 8 hours, where the temperature of the water is maintained at about 38°F. by the use of ice or brine coils. The fats are next drained free of water and run through a hasher which chops the fat into small fragments.

The chopped fat is placed in water-jacketed kettles equipped with mechanical agitators. Usually the kettle is heated slightly and the agitator started before the fat is added, together with a measured quantity of finely ground rock salt. More fat and salt are added in the same proportion until the kettle is filled. The kettle is heated until the temperature of the fat has reached 155°F. and the fat has melted. The material in the kettle then is allowed to settle and the fat is drawn from the top into a clarifying kettle by means of a movable suction pipe. The last

traces of fat are skimmed off and placed with the next batch of fat to be thus treated.

The clarifying vessel has a cone-shaped bottom, from one side of which runs a siphon. A small amount of salt is sprinkled over the surface of the fat, and then it is allowed to settle for three hours at a temperature of around 140°F. A sample is withdrawn from the bottom to test for the presence of water. If the results of the test are satisfactory, the fat is withdrawn through the siphon into vats of wood or metal mounted on trucks. These boxes or trucks, are known as "seeding" or "graining" boxes or trucks, since at the temperature of the room into which they are run, 85 to 90°F., the stearin and palmitin crystallize and the stearin appears seedy or granular. Usually about three days are required for the separation of the solid fats from the oil.

At a temperature of 89°F. the oil is pressed from the grained stock by means of mechanical or hydraulic presses. The material is put into the press after being folded into press cloths, which are stacked on top of each other in exactly the same way that ground apples are packed in a cider press. The oil runs off into iron tanks where it is heated to 115°F. and then run into tierces. After all the oil has been pressed from the stock, the stearin is removed from the press, cooled, and then packed in barrels. Were cooling not done, mold spots would be likely to appear. Oleo stearin is used for lard substitutes, candles, and as a filler for candies and leather.

Meat Preservation by Salting and Pickling.—The preservation of meat may be accomplished in numerous ways including the use of refrigeration, canning, drying, and salting, pickling, and curing. The latter methods are of ancient origin and are widely used at present, both in the modern packing house as well as in rural communities. On the farm and in isolated regions where refrigeration facilities are less likely to be available than in large towns, the use of salt and other chemicals for meat preservation is of greater relative importance. Salting is often followed or combined with other processes, such as smoking, which improve both the flavor and keeping qualities of special products including hams, shoulders, bellies, and bacon.

In the use of salt as a preservative, either alone or in combination with such compounds as saltpeter, nitrates of sodium or potassium, there are several objectives. It is necessary to prevent spoilage by microorganisms, but in addition the final product must have a desirable taste and flavor. The appearance must also be attractive. It has been common practice for many years to use saltpeter in combination with salt in the pickling solution because of increased efficiency in curing meat products. More recently the nitrites have been found even more effective.

The nitrates serve a useful purpose in respect to the appearance of the products because when they are present, certain changes take place whereby the hemoglobin of the meat tissues is chemically combined to form nitrosohemoglobin. This compound imparts a relatively bright red color to the meat which is much more attractive than products treated with salt[1] only. The nitrates likewise exhibit an inhibitory effect on spoilage bacteria when used in relatively small amounts. When sodium nitrate is used as an ingredient of pickling solutions, there are some types of bacteria normally present in meats which have the ability to convert nitrates to nitrites. The nitrites are more effective than nitrates in checking spoilage and also have the color-fixing ability. In recent years very small quantities of sodium nitrite have been used in pickling solutions, along with salt and saltpeter. According to Moulton, sodium nitrite has ten times the inhibiting action of sodium nitrate.[2]

In 1935 a new method of curing meats was advocated by Hall, using an acid pickling solution containing salt, sodium nitrate, sodium nitrite and citric acid or some other acid.[3] This method is said to accelerate the conversion of the nitrite to nitrous acid which is the compound which actually combines with the hemoglobin to form the desired color complex.

In addition to the compounds cited, sugar is also used as a constituent of pickling solutions. Many of the solutions containing sugar are called sweet pickling processes. In some instances the so-called dry sugar cures may be used, in which case the meat is packed in tight containers and sprinkled with dry mixtures of salt, sugar and small quantities of nitrate or nitrite. As the meat is in tight containers, the resulting meat juice extracted by the curing mixture forms a brine or pickle which accomplishes the same results.

When a pickling solution is used, it requires some time for the curing agents to penetrate through the tissues, and the spoilage types of bacteria may cause damage before their growth is inhibited. This is particularly apt to happen in hams and fatty products where the penetration is likely to be slow and uneven. In order to prevent spoilage under such conditions, it has become a common practice to pump the pickling solution into the interior of the meat. This is done mechanically by inserting a perforated needle or hollow tube into the product to be cured and forcing the solution through the tube into the tissues by means of a manual- or foot-operated pumping device. This is specially helpful in meats containing fatty tissues in large proportions. When the bones are left in the product to be cured, the needle is often inserted in those portions close to the bone, as the spoilage frequently has its origin in the vicinity of

[1] Hoagland, R., Bur. Animal Ind., U. S. Dept. Agr., 25th *Annual Report*, 1903.

[2] Moulton, C. Robert, Meat through the Microscope, 1929.

[3] Hall, L. A., *Food Ind.*, **7**, 533, 1935.

the joints. The use of brines or salt pickling is well adapted to pork, bacon, and other fatty meats, although lean meat, veal, and mutton may become too dry by such processing.

It is a common practice to smoke some salt-cured meat and meat products. The smoking process preserves not only on account of some drying of the meat through the heat applied during smoking but also on account of the chemicals deposited on the surface. These compounds may penetrate somewhat into the meat and tend to inhibit bacterial growth and action.

Instead of smoking meats it is possible to use a specially prepared salt which is marketed by some of the salt-manufacturing companies. Such salts have a pleasant smoked flavor which may be imparted to meat by using dry-curing processes and eliminating the smoking operation. This method is not commonly used commercially, however, but may attain some use in small-scale and farm meat-curing.

Meat Preservation.—Meats may be preserved by means other than refrigeration, although chilling is the first step, and preliminary to any further treatment. Many meats are subjected to salting and pickling processes which may be further supplemented by smoking. The use of salt (sodium chloride, $NaCl$) as a preservative has been common for many centuries, and as a means of limiting bacterial spoilage it depends on the inhibitory effect of salt and the concomitant dehydration of the food material by the use of salt in high concentration. In modern pickling operations, sugar, Chile saltpeter (sodium nitrate, $NaNO_3$), and more recently small amounts of sodium nitrite ($NaNO_2$) are frequently used in addition to salt. With some types of meats the salt is added to the meats in a dry form and with others the meats are immersed in a brine containing one or more of the above constituents.

In order that incipient spoilage should not develop in these products before the curing agents have penetrated the cuts of meat sufficiently to inhibit bacteria, the pickling and salting operations are usually conducted in cellars or rooms refrigerated so the temperature is below 40°F. However, higher temperatures may be used if the composition of the pickling material is properly adjusted.

With large cuts of meat or with hams, the osmotic changes may require considerable time periods before the brine has "struck" or become thoroughly diffused throughout the tissues, and the time, as well as the spoilage, may be reduced to a marked degree by "pumping" the pickling solution into the tissues by means of a large syringe under pressure. This enables a uniform saturation of the pickling solution in a relatively short time compared with the pickling under normal circumstances, which may take several weeks.

In Europe a number of different methods have been suggested to accomplish the same purpose. One depends on injecting the brine by pressure into the heart of the still bleeding animal. Another depends on injection into a blood vessel under pressure after rigor mortis has set in. A third method consists of subjecting the meat to a vacuum and then subjecting it to a brine under pressure for several hours. None of these methods have been widely adopted in the United States, where pumping is quite commonly practiced.

The exact composition of the pickling solution has depended largely on custom in the past, but much attention has been paid to this question in the past decade as it is closely interrelated with the extent of bacterial spoilage, particularly in hams. Work of this nature carried out at the Institute of Meat Packing in Chicago and reported by Moulton in "Meat through the Microscope" indicates the effectiveness of nitrites in pickling solution as compared with nitrates or salt in much higher concentration. The sugar in some pickling formulas is for flavors rather than any preservative action. Salt, of course, is a flavoring material as well as a preservative. Sodium nitrate and sodium nitrite have another important characteristic in that they have the chemical ability of combining with the hemoglobin of meats and forming a relatively stable pigmentation which resembles fresh meat in color. This ability on the part of the nitrates appears to be due to the fact that nitrates may be reduced in part to nitrites by bacteria in a pickling solution after the lapse of time, and the nitrites are really the active agents. A similar fixation of the red color is said to be possible through the use of dibasic phosphates or nitrogen dioxide. Carbon monoxide will also combine with hemoglobin in a similar color reaction and has been used experimentally, in combination with refrigeration, as a means of meat treatment.

According to Ostertag,[1] Trichinae and Cysticerci are rendered harmless in ordinary pickling operations. The effect of pickling on bacteria causing various infectious diseases, such as swine fever and swine plague and those caused by the tubercle bacillus, the paratyphoid and enteritidis groups of bacteria, is not to be relied on for killing such organisms.

During the pickling process some of the nutrients in the meat which are soluble in brine, such as nitrogenous materials and phosphoric anhydride, are lost. In spite of these losses the weight of the meat increases, owing to absorption of brine.

Pork Curing. *Bacon and Hams.*—Pork is sometimes dry-cured by rubbing with salt and piling it up in stacks in curing cellars which are kept at relatively low temperatures. A small percentage of saltpeter may be

[1] Young, Ostertag's Textbook of Meat Inspection, Bailliere, Tindall & Cox, London, 1934.

added to the salt to assist in the coloring of the tissues. If the cuts are packed by layers in boxes, tierces, or vats and dry salt and other curing agents added between the layers, there will eventually be a brine formed, owing to the extraction of water from the tissues.

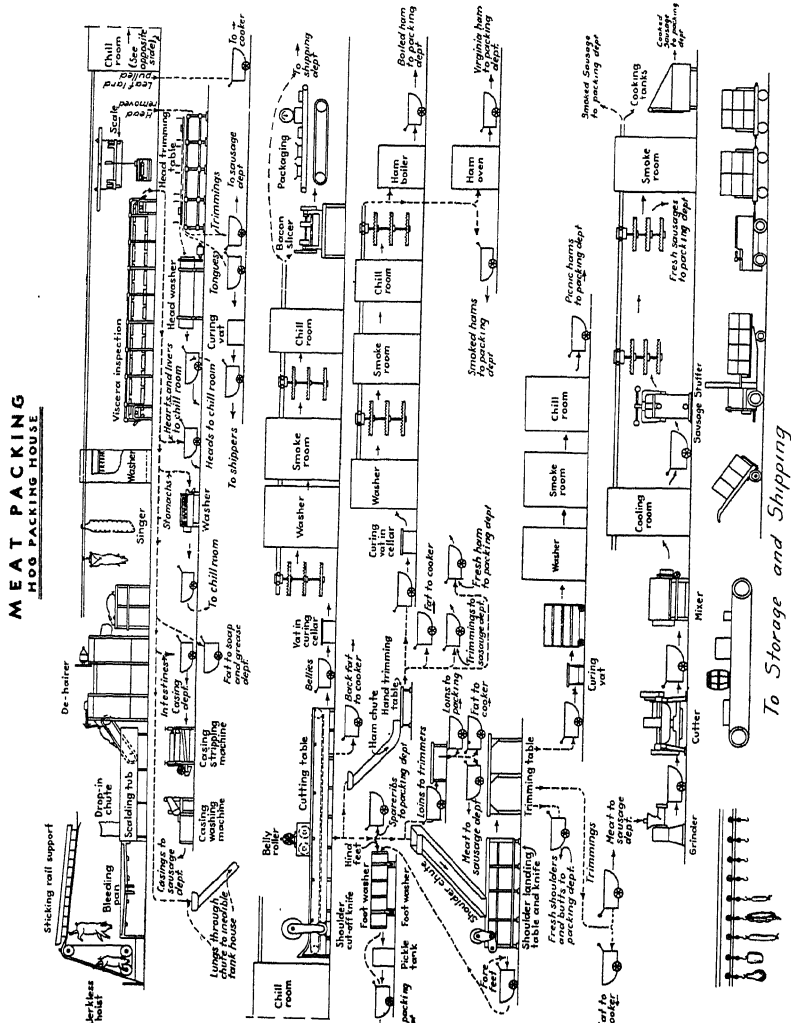


FIG. 28.—(*Food Industries.*)

This method is commonly used for bacon which requires several weeks to cure, after which it is removed from the brine, soaked in water for a short time, and smoked. The soaking may be omitted if the meat is subjected to a spray of hot water followed by drying with a compressed-

air jet which evaporates the excess moisture on the surface. The cuts may then be threaded with string and suspended from smoke strips or "trees" so that each piece will have ample opportunity for contact with the smoke. Smokehouses may be several stories high, with grating floors. In this case the upper floors are loaded first so that condensation of moisture from the warm air on the cold meat is prevented from dripping on the meat hung on the lower floors. Some modern smokehouses have mechanical conveyors on which meat is hung. The endless chain can be regulated to run at any rate of speed and conveys the product slowly from the top to the bottom of the smoking chamber which may be four or five stories in height.

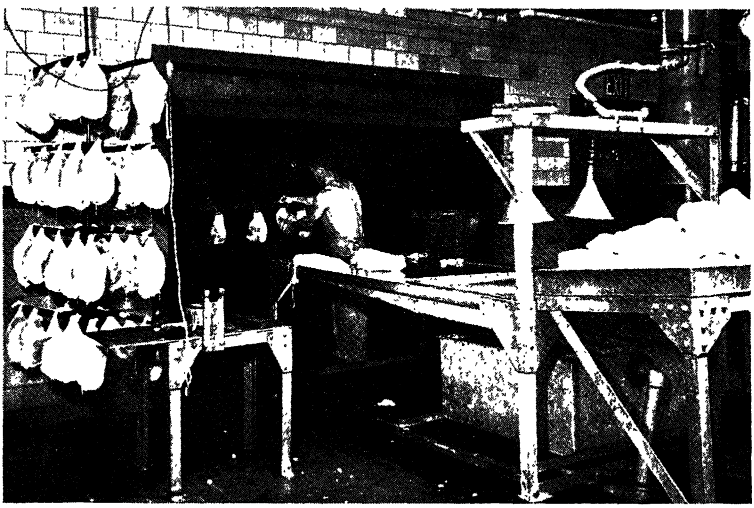


FIG. 29.—Hanging meat in a conveyor smoke chamber. (*Food Industries.*)

Bacon is usually dried for a number of hours in the warm air of the smoking chamber before the actual smoking is started. Gas burners are often used as a source of heat and hardwood sawdust burned with incomplete combustion to produce the smoke. The temperature in the newer smokehouses is often controlled automatically by thermostats. In some establishments the smoking is continued for a number of days, thereby causing hardening of the exterior, leaving a deposit or film of creosote and other products from the smoke, and drying the meat somewhat. Temperatures from 100 to 120°F. are used in many plants. When the smoking is completed any salt which has crystallized on the exterior is brushed off and the bacon packed in boxes, barrels, or other containers for shipment. Some bacon, sliced or unsliced, is now packed in transparent parchment to keep it clean and preserve its appearance. Bacon may also be canned.

Hams, which make up one of the most valuable meat products from hogs, are the hind legs of swine from above the hock. There are many kinds of hams, depending largely on the type of curing process and the methods of smoking used. The flavors are due in part to the pickle, which may contain sugar along with the other agents mentioned above. Flavors may also be due in part to the wood used in smoking. Hickory, maple, mahogany shavings, and other woods are used in the United States, while juniper is said to be favored in Germany and birchwood in other parts of Europe. Most hams contain an abundance of fat, but Virginia hams, which are quite noted for quality and flavor, are relatively lean. Their famous flavor is said to be due in part to the character of the food with which the hog has been supplied.

The function of the smoke is not merely to impart the characteristic flavor, but it also serves to inhibit the microorganisms which gain access to the surface of the meat.

Meat Freezing—Rather wide differences of opinion are prevalent in different countries concerning the proper temperature for freezing meats. According to Moran[1] the practice in Germany is to use −6°C. (21.2°F.), in Australasia −11°C. (12.2°F.), while in America much lower temperatures may be used, with subsequent storage at approximately −10°C. (14°F.).

The structure of muscle tissue, which makes up a considerable portion of our fresh meats, is essentially a combination of millions of water-bearing fibers, each approximately 0.0025 in. in diameter and 1 to 2 in. in length, and which are inclosed in an extremely thin sheath or sarcolemma. Groups of these fibers are inclosed in the connective tissue in which the nerve fibers and blood vessels are located.

The speed with which the freezing process is conducted has an important bearing on the future quality of the product as it has been shown that with slow freezing, the ice crystals which are formed are largely located outside the muscle fibers and build up by accretion, whereas with more rapid freezing throughout the mass the crystals are within the fibers and may be more distributed and much smaller in size. The latter distribution is believed to be advantageous in preserving the quality of the frozen meat although the reasons involved are controversial.

The temperature used will determine the amount of ice formed, and likewise the concentration of salts and other water-soluble substances which comprise the unfrozen remainder. Experiments by Plank have shown that a temperature of −55°C. must be attained before beef is entirely frozen.[2]

[1] Moran, T., *Refrigerating Eng.*, **12**, 343, 1926.

[2] See also Poole, G., *Refrigerating Eng.*, **31**, 3, 1935.
Plank, R., *Z. ges. Kälte-Ind.*, **32**, 141, 1925.
Plank, Ehrenbaum, Reuter, *Z. ges. Kälte-Ind.*, Heft 4–9, 1916.

After the death of any animal there occurs a condition known as rigor mortis, during which the semifluid contents of the muscle fibers tend to stiffen or gel, but after a period of time this condition is reversed and the fibers return to their original physical state. These changes are intimately connected with the water content of the muscle tissue, some of which may be considered as free or bound only by osmotic forces in contrast to that which is fixed in some sort of physicochemical combination with protein and therefore less able to migrate under various temperature conditions. According to Moran, water passes from the fibers into the interfibrillar spaces during slow freezing, owing to the fact that the lymph or fluid between the fibers has a higher freezing point than that of the water complex in the fibers; under this condition, if the rate of freezing is sufficiently slow, freezing will occur in the lymph.

Microscopic investigations have demonstrated that ice crystals thus formed may mechanically rupture the thin sheath of the muscle fibers, but there is also a possibility that the chemical composition of this sheath may be subject to irreversible reactions caused by low temperatures; as a result the permeability may be affected in such a manner that on return to normal temperatures the water cannot be reabsorbed through these membranes to the desired extent.

An equation to calculate the necessary freezing time has been advocated by Plank.

$$= \frac{Ld}{2\theta}\left(\frac{1}{2C_1} + \frac{1}{C_2} + \frac{d}{8k}\right)$$

where L = latent heat of fusion of ice, in calories per cubic meter.
d = maximum thickness of body, in meters.
θ = difference in temperature between freezing medium and freezing point of the body.
C_1 = coefficient of heat transfer from the frozen surface layer to the freezing medium (4,000 for frozen brine; 8 for moving air).
C_2 = coefficient of heat transfer from the unfrozen inner portions of the mass to the adjoining layer (500 cal. per square meter per hour).
k = thermal conductivity of the frozen layer (2 cal. per square meter per degree centigrade per hour).

This formula assumes the absence of fat in surface layers.

The optimum conditions for thawing frozen meat are important because very rapid thawing may result in "drip." This moisture is a part of the original water content of the animal tissues which has been crystallized in the freezing process, but which melts when the meat is thawed out. Unless conditions are favorable for reabsorption in the

animal tissues and sufficient time is available for it to be absorbed, the water will be lost.

Australian workers have advocated the freezing of meat within 30 minutes and thawing the meat very slowly to minimize the amount of "drip."

In order to accomplish freezing in the briefest time interval the need of using small-sized cuts is obvious. Those more than a few inches in thickness require freezing times sufficiently long to take them out of the category of quick-freezing.

Lard.—Lard is the fat separated from the adipose tissues of hogs for use as a food. Three kinds of lard are manufactured on a commercial basis: prime-steam, neutral, and kettle-rendered lard.

The rendering tank for the production of prime-steam lard is constructed of heavy steel, built to withstand pressure and corrosion, and insulated to prevent heat loss. The tank is equipped with a steam inlet, a manhole at the top through which the material is put in, draw-off cocks for the withdrawal of the melted fat, a gate valve for withdrawal of the extracted material, a safety valve, and other necessary features.

Loading the tank is an important feature. As a rule, bones or heads are placed in the bottom of the tank, water is run in until the tank is about a third full, and then the remaining fatty material to be rendered is added. Water keeps the material from packing, which would result in a much slower heating of the fat.

When the tank has been filled, the water is heated to boiling by steam, and later run out of the tank through the bottom. Blood and other extraneous material is thus removed. More cold water is admitted into the bottom of the tank, and then the steam is turned on. The operation of the tank from now on is much like that of an autoclave. A valve is kept open until the air has been displaced and then it is almost, but not entirely, closed. The pressure is increased to 40 lb. per square inch and the material in the tank is then cooked. At the end of the heating period there is a layer of water with any solid material present at the bottom of the tank, with a layer of lard stratified above. Extreme care must be exercised in releasing the steam pressure, for if it is reduced too quickly, some of the water vaporizes into steam with the result that water is blown up through the lard, forming an emulsion. Lard which has been injured in such a manner cannot be sold as first-quality lard, therefore the pressure is reduced very slowly.

A small quantity of salt is added to the tank to bring about a better separation of the lard and water, and a period of 2 hours or longer is allowed for the materials to settle. The lard is then drawn off through the proper draw-off cocks. It is further treated to remove all possible traces of water because water may contain nitrogenous material and favor

the fermentation and souring of the lard. Having been dried, the lard may be barreled as prime-steam lard, or further refined.

Refining is for the purpose of clarifying, removing moisture and impurities, and bleaching to a slight extent. The lard to be refined is run into a tank equipped with facilities for heating the lard and with some means of agitation, either mechanical or by air. Air does not cause the materials to mix so well as mechanical agitation and favors the development of rancidity. Suitable clarifying and bleaching agents are added in small quantities, the mixture heated to 160 to 180°F. and agitated. The lard thus treated is passed through a filter press until clear and is pumped into a tank.

Fuller's earth, carbon blacks, and diatomaceous earths are used as clarifying and decolorizing agents. Fuller's earth is most popular. Diatomaceous earths are excellent clarifiers, since they do not impair the flavor or keeping qualities of the lard, but they do not decolorize. Most of the agents used may exert a harmful effect upon both flavor and keeping quality, hence as little of the material as is consistent must be employed and still obtain the desired results. Carbon blacks when used alone are difficult to remove from the lard. They may be mixed with fuller's earth.

Lard is packed and sold as smooth or grainy lard. Smooth lard is lard which is cooled quickly to prevent the separation of the oil and stearin. It is precooled to about 110°F. and further cooled by a lard roll, a metal cylinder cooled within by means of brine or by the direct expansion of ammonia. On one side, the revolving roll dips into the rather warm lard (110°F.) and takes up a layer, the thickness of which is regulated by a bar. By the time the lard has arrived at the bottom of the other side it is sufficiently cooled (60°F.) and is scraped off in sheets. It is directly packaged or placed in a tank with an agitator until wanted. Lard cooled in this fashion is said to be able to withstand a higher temperature without softening than lard which has been cooled slowly.

Grainy lard is preferred by certain consumers. It derives its name from the grainlike appearance of the solid portion which results from cooling. On cooling the liquid portion is not mixed and separates out. Grainy lard can be prepared in one of two ways: it may be allowed to grain in the tank into which it has been pumped following refining, agitated to mix the separated oil and solid portions, and packaged; or it may be poured while hot directly into the packages, pails, or tubs, where it will grain. In the latter case, the covers (tin covers for tins) are not put on until the lard has "set," and the tins are stored at about 40°F.

Lard may be stored in tubs, pails, barrels, tins, boxes, etc. Sodium silicate is sometimes used on the inside of wooden tubs and pails in order that lard may not be absorbed and thus wasted. Paraffin is employed often instead of silicate in barrels or tierces. Barrels ordinarily are

coated with paint, varnish, or oil to prevent dirt from being ground in as the barrels are rolled around. All containers must be clean before using.

A temperature of from 50 to 60°F. is suitable for the storage of lard. Lard may be transported for long distances without refrigeration, except in the case of very warm weather or in warm climates.

Neutral Lard.—Neutral lard is manufactured mainly from back fat and leaf fat. The material is chilled, cut up very fine, and placed in a water-jacketed kettle. The water in the jacket is slowly heated causing the lard to separate from the fibrous material. Lard obtained by this process is white, but without definite flavor. It is used in the manufacture of margarine without further treatment.

Kettle-rendered Lard.—Lard of this kind is made from the better grades of fats. The fats are hashed into steam-jacketed kettles, the moisture boiled out, the fat separated from the fiber and then put up in packages while still hot.

TABLE 66.—UNITED STATES PRODUCTION OF LARD, OLEO, AND STEARIN, 1929

Product	Pounds	Value
Lard..................	2,041,210,887	$248,007,633
Oleo oil and stock......	113,230,636	12,403,313
Stearin (oleo and other).	38,542,996	3,819,386

Lard made by this process has the best flavor, but the color is darker than that of lard obtained by steam treatment, and lower yields are obtained.

Lard by Dry Rendering.—Briefly, the process consists of hashing the small pieces of fat, crushing the bones, and placing them in a steam-jacketed cooker. The cooker is equipped with agitators which keep the material in constant motion and clear the sides of the apparatus so that steam readily comes into contact with the material. During the cooking the moisture is driven off from the fatty substances and is expelled through vents in the cooker or removed through the use of vacuum. The dried material is next placed in an apparatus with a false bottom, which permits the oil to drain off, but retains the fibrous material. The lard from this treatment is clarified by filtering, and then processed in a manner similar to that of steam lard, as outlined above.

Dry rendering is a comparatively new method. It involves a preliminary hashing of the materials or crushing to reduce the size of bony structures and subsequent heating of the material in horizontal steam-jacketed cookers equipped with internal agitators. No water is added in this process, which may be used instead of the steam-rendering method outlined previously. The water present in the fatty tissues is eliminated

as steam or may be taken off at lower temperatures by the use of a vacuum pump. When the cooking is completed the contents of the cooker drop into tanks equipped with coarse filters which enable the lard to pass through but hold the organic and solid materials. The lard is then clarified and refined while the retained material is pressed and used for feeds. The flavor of such lard is somewhat different from the steam-rendered product.

The same method of dry rendering may be used for the production of inedible tallow and greases. According to Clemen[1] dry rendering

Table 67.—Lard Produced, 1931

State	Quantity, lb.	Value
Illinois	379,494,632	$ 30,711,147
Iowa	211,969,160	18,219,596
Minnesota	122,396,723	10,548,247
Kansas	111,859,214	9,810,962
Ohio	107,873,657	9,213,350
Nebraska	106,713,369	8,713,587
United States	1,749,797,684	$149,491,933

offers distinct advantages in minimizing the formation of fatty acids which are undesirable and conserves nitrogenous compounds such as ammonia and other protein derivatives which are valuable in the feeds made from the cracklings.

Rendering of Beef Fats.—Beef fats are rendered to produce oil, stearin, and tallow. Oleo oil finds its use in the making of margarines and as a shortening for bakers, while stearin is used in the confectionery industry and as a component of some lard substitutes. Edible tallow is also used for the latter purpose.

In making oleo stock the better grade fats are used, such as caul, ruffle, heart, pluck fats, and that from the alimentary tract. As they come from the killing floor these fats are cut out, washed, and chilled in cold water in order to reduce the temperature in the shortest possible time to prevent changes which lower the quality of the product. Frequently the fats, sometimes cut up to reduce the size of the pieces, are left over night in water in tanks refrigerated to below 40°F., which also facilitates the hashing which follows.

The chilled fats are later drained, run through a hasher or grinder and dropped into a water-jacketed melting kettle. These kettles have a

[1] For a more complete discussion of rendering and other meat-by-product technology, see R. A. Clemen, By-products in the Packing Industry, University of Chicago Press, 1927, to which source the authors are indebted for material on this subject.

mechanical agitator which revolves slowly during the filling operations and until the melted fat, which is heated slowly, reaches 150 to 160°F. During the filling, salt is added to assist in separating the fat by increasing the specific gravity of the water, thus making a more complete separation. After the agitator is removed the contents of the kettle are allowed to stand to complete settling of the scrap and nitrogenous materials. Then the fat is drawn off from the top and run into another kettle where it is further salted and allowed to stand for several hours. During this period the remaining water settles to the base of the kettle and is drawn off separately. The oleo stock is then run into tanks or trucks and allowed to stand at temperatures of 85 to 90°F. for several days, during which period the stearin and palmitin crystallize and solidify, "seed" or "grain," while the oleo oil, because of its lower melting point, remains a fluid. This separation is not complete and must be followed by the use of a press. The mixture of solid fat and oil is put in light duck press cloths, the cloths folded together, racked up and subjected to hydraulic pressure. This application of pressure on the still warm material forces the fluid oleo oil through the press cloth and leaves the solid stearin in a thin layer within the cloth. The warm oil flows into containers below the press until only small amounts remain in the cloth, when the pressure is released. The stearin is removed from each of the press cloths and placed in conveyors going to the packing room or to the appropriate by-product-manufacturing department.

Those beef fats of lower grade are usually rendered to produce edible tallow. This may be accomplished in several ways but the most common method in large plants is to cook these fats, which include all edible fats not used for oleo and stearin, in a steam tank with a pressure of 40 lb. per inch. This cooking is done with only a small amount of water in the base of the vertical tank, although when filled and during the earlier preliminary heating process, water is present in the tank. Before the pressure cooking it is removed, however.

Sausage.—Sausage includes a number of meat products, prepared in whole or in part from chopped meat and condiments, sometimes with added cereals, which are forced into casings of various shapes and sizes. These products are widely used in Europe and are quite popular in America.

The materials used in sausage in establishments under Federal inspection are all of good edible materials but are often trimmings and parts of animals which have no great demand in their natural form. Usually only beef and pork are used for sausage manufacture. Bull meat is said to be particularly desirable for sausage making, owing to its ability to absorb water. The cereals are allowed in only small percentages, over 2 per cent based on the weight of meat requiring special labeling. The

spices used include salt, sugar, saltpeter, vinegar, onions, garlic, allspice, mace, pepper, paprika, sage, caraway, and numerous others, depending on the particular type. Water is sometimes added to the above ingredients in limited amounts.

If the product is in the class of fresh sausage, it requires constant refrigeration after the constituents have been ground, mixed together, and stuffed in casings.

Smoked or cooked sausage products include such types as frankfurters, bologna, blood sausage, headcheese, etc. The meats used in these products are sometimes cured before mixing, or the finished product may be cured after being stuffed into casings by adding curing agents to the meats in the grinder and later subjecting the material to a sweating or curing process. Many such products are subjected to a smoking process to improve the flavors and keeping qualities. After smoking, the products are in many instances subjected to a hot-water-cooking process which renders the material safe from a health standpoint. The size of the units determines the length of cooking necessary to reach the desired internal temperature required—137°F.—which will kill trichinae. Immediately after cooking is completed the products are cooled and refrigerated.

Dry sausage or summer sausage is made of the highest grade products, largely pork and beef trimmings. As it is not cooked in manufacture, the meat used must be previously treated by curing, refrigeration, or drying to kill any trichinae present. The meat is chopped by a special mechanical device or rocker, mixed with the other ingredients, and later smoked, usually employing temperatures well below 100°F. for one or two days, depending on the product.

The following descriptions of the more common types of sausage and their general ingredients are cited by Hoagland.[1]

Frankfurter-style sausage of the best quality is prepared from meat, usually a mixture of beef and pork trimmings and certain beef cuts. The ground mixture is stuffed in animal or artificial casings and is then smoked and cooked for a short time. Cheaper grades of frankfurter-style sausage are made of a mixture of meat and meat by-products. Cereal is frequently added to these grades of sausage.

Bologna-style sausage is prepared from ingredients similar to those used in frankfurter-style sausage and in a similar manner, except that the former is stuffed in larger casings or other containers and is cooked for a longer time. The cheaper grades of this product are made from much the same materials as those used for the same grades of frankfurter-style sausage. Kosher bologna-style sausage and kosher frankfurter-style sausage contain no pork.

[1] *U. S. Dept. Agr. Circ.* 230, 1932.

Pure pork sausage is prepared exclusively from pork, usually lean-pork trimmings, but certain lean-pork cuts are used to a limited extent. The ground mixture is stuffed in animal casings or is packed in other containers. This is an uncooked product.

Fresh link sausage, not pure pork, is made from beef and pork trimmings with or without the admixture of meat by-products. Cereal is frequently added. This sausage must be cooked before being eaten.

Braunschweiger-style sausage is a high-grade smoked and cooked liver sausage prepared from livers and pork trimmings. This product is stuffed in large hog casings.

Liver pudding, or liver sausage, is manufactured chiefly from meat by-products and may contain a moderate proportion of meat. Cereal is frequently added to this product. Liver pudding is thoroughly cooked in the process of manufacture.

Headcheese is usually prepared from a variety of meat products from swine and cattle and may contain a moderate proportion of meat. Pig tongues are a frequent constituent of headcheese. This is a cooked product.

Blood sausage is a cooked product prepared from beef blood, and it may contain coarsely chopped fat pork and tongue.

Meat loaf is usually prepared from a mixture of beef and pork. Veal is used occasionally. Sometimes the loaf is prepared from meat, meat by-products, and cereal. The finely ground mixture is molded in pans and thoroughly cooked.

Souse is prepared from a mixture of meat and meat by-products containing a considerable proportion of connective tissue. The product is thoroughly cooked, vinegar is added, and the mixture is molded into pans.

Luncheon roll is a cooked product containing coarsely ground beef and pork. The ground meat is cured for a short time and then stuffed in cloth bags.

Polish-style sausage is prepared from coarsely chopped pork and beef and is characterized by the presence of garlic as seasoning. The ground meat is cured and is then stuffed in hog casings. This is a cooked sausage.

Country-style sausage is a smoked, uncooked product usually prepared from ground pork. This product is stuffed in hog casings.

Bockwurst is usually prepared from meat and eggs with or without milk and does not contain cereal or similar substances. The mixture is ground fine and stuffed in sheep or hog casings. The product must be cooked before being eaten.

The following table includes the composition of some of the more common types of sausage, as shown by chemical analysis, by Hoagland.

TABLE 68.—AVERAGE CHEMICAL COMPOSITION OF CERTAIN KINDS OF SAUSAGE AND OTHER MEAT FOOD PRODUCTS

No. of samples	Product	Water, per cent	Ash, per cent	Fat, per cent	Nitrogen, per cent	Protein ($N \times 6.25$), per cent	Starch, per cent	Fuel value per pound, calories
8	First-grade frankfurter-style sausage	60.88	2.64	22.00	2.19	13.69	....	1,150
8	Second-grade frankfurter-style sausage	61.33	2.95	19.70	2.32	14.51	....	1,067
8	Frankfurter-style sausage with cereal	64.29	3.12	14.06	2.44	15.24	1.20	872
9	First-grade bologna-style sausage	63.98	2.82	18.11	2.30	14.35	....	1,000
7	Second-grade bologna-style sausage	64.03	3.16	17.34	2.32	14.48	....	971
10	Bologna-style sausage with cereal	62.38	3.31	15.92	2.36	14.78	1.81	951
14	Pure-pork sausage	41.93	2.09	44.83	1.73	10.81	....	2,026
10	Fresh link sausage	44.75	2.48	41.17	1.80	11.28	....	1,885
11	Braunschweiger-style sausage	56.20	2.67	23.75	2.46	15.39	....	1,248
9	Liver sausage (liver pudding)	58.97	2.23	20.57	2.67	16.69	....	1,143
11	Headcheese	62.04	2.35	20.26	2.41	15.04	....	1,100
13	Blood sausage	47.09	2.30	34.64	2.37	14.81	....	1,683
12	Meat loaf	63.99	3.52	13.45	2.58	16.14	....	865
12	Souse	72.87	1.87	12.34	2.11	13.18	....	743
12	Luncheon roll	56.43	3.39	23.79	2.54	15.89	....	1,260
10	Polish-style sausage	56.04	3.55	23.06	2.63	16.41	....	1,239
9	Country-style sausage	51.74	3.92	27.45	2.59	16.21	....	1,414
8	Bockwurst	63.53	2.43	21.85	1.87	11.79	....	1,104
4	Beef chuck (medium fat)*	68.30	0.90	11.90	....	19.60	....	841†
19	Pork-loin chops (medium fat)*	52.00	1.00	30.10	....	16.60	....	1,304†

* ATWATER, W. O., and A. P. BRYANT, The Chemical Composition of American Food Materials, *U. S. Dept. Agr., Off. Exp. Sta. Bull.* 28, 1906.

† The fuel values of beef chuck and pork-loin chops have been recalculated on the same basis as that followed with the other products in this table.

GELATIN

Gelatin is a food product which has gained wide usage, particularly in the form of desserts. Its ability to incorporate within its own mass many times its weight of water, to which a great variety of flavors and colors may be added, makes gelatin a favorite base for desserts and salads in the home. In the commercial ice-cream industry gelatin has attained wide use as a stabilizer, the incorporation of less than 1 per cent to the ice-cream mix causing a marked improvement in texture and composition of the frozen product. In confectionery manufacture the ability of gelatin to act as a protective colloid and emulsifying agent enables its utilization in the manufacture of marshmallows, creams, kisses, gum drops, pastes, and fondants of many kinds. The baker uses gelatin in icings, meringues, and fillings. Recent experiments have indicated that the use of gelatin as a supplementary food in the diet of infants may be beneficial.[1]

[1] ELTERICH, BOYD, and NEFF, *Arch. Pediatrics.* **47**, 286, 1930.

One of the very important industrial uses of gelatin is in the photographic industry where a coating is necessary for the light-sensitive films. Gelatin is sometimes used in the textile industry as a sizing agent. The pharmaceutical industry uses gelatin for capsules.

The production of edible gelatin is carried on in Illinois, Massachusetts, Michigan, New Jersey, New York, and Wisconsin. The average quantity manufactured in this country from 1927 to 1935 has been approximately 16 million lb. per year. In 1935 the production was over 18 million lb., which came from 11 plants, according to the U. S. Department of Commerce, Bureau of Census. In 1934 this country imported 878,000 lb. of gelatin, three-fourths of which was of edible grade, while during the same period 228,000 lb. of gelatin, all of inedible grade, was exported.

The processes used in making gelatin are very similar to those of the glue industry, but more care is taken in making gelatin. If both products are made by the same company, the glue is made in a separate plant because of odors which would make the gelatin unacceptable for its edible uses.

The production of gelatin is a specialized industry closely related to the packing house because the raw materials for gelatin are by-products of animals. The principal raw materials are hide and skin trimmings and shavings, certain bones from cattle, horn pith, and pig skins. Ossein, a bone material which has previously been treated with acid to remove the calcium and phosphates, is also used as raw stock for gelatin. Some of these materials are obtained directly from slaughterhouses or may come from tanneries or other sources. In Europe one source of material for gelatin is the dried bones of water buffalo which have been imported from India. The remnants or trimmings from bone-button factories may also be used.

The processes used in various plants differ, depending on the raw material, but the purpose involved in each case is identical, *viz.*, to bring about eventually a hot-water extraction of collagen from the raw material at definite temperatures and to concentrate the extract subsequently by removal of water.

When hides or hide fragments are used the raw material is first shredded into thin strips by a revolving cutting device known as a hog. The strips are thoroughly washed in water, then put in liming pits with a solution of freshly made milk of lime. The hides swell greatly in this so-called plumping process, which may be allowed to continue 6 to 12 weeks or more, during which time the lime is drained once or twice and replaced by a fresh solution. When the liming has been completed, the skins are removed to vats or drums where they are washed and agitated for a number of hours until the lime has been largely removed. The remaining lime is neutralized with acid, hydrochloric or sulphuric acid

being the more commonly used, and the skins left in a slightly acid state so that the pH is lower than that of both the isoelectric points of the gelatin to be extracted. The skins may be subjected to another washing process previous to being placed in the cooker or heating tank, where they are cooked in water heated by steam coils.

Pig stock or pork hides and some other raw materials may be limed, or instead, subjected to an acid treatment previous to the cooking and extraction. The acid treatment is completed in a much shorter time than when the lime treatment is used.

Careful temperature control of the cooker is essential as the temperature at which the extraction is made is of great importance in determining the quality of the gelatin resulting. Three or more separate extractions may be made from the same batch of skins, with the first one carried out at approximately 140°F. and the others at progressively higher temperatures to 170°F. or above. Each of the extractions is carried on at a definite temperature until the desired concentration of extractives has been obtained as determined by hydrometer or specific-gravity tests. The extract is drawn off from the bottom of the cooker to eliminate the presence of fats or oils. The cookers may be constructed of wood, metals such as aluminum or the resistant alloys, or are sometimes enamel- or glass-lined.

While the extract is still hot, it is run by pipe lines or open troughs into reservoirs from which it passes to filters. These filters may be plate and frame presses using kieselguhr on canvas duck as a filter medium, or they may be cellulose-pulp filters.

There are a number of methods by which the filtered extract may be treated. In one method it is poured into rectangular metal pans with a capacity of approximately 1 cu. ft., which after filling are immediately subjected to refrigeration, under which conditions the extract sets or gels, may later be cut in sheets for the subsequent drying process. In other cases the extract may be pumped to an evaporator where it is concentrated to a 5 to 10 per cent solution, then spread on rubber conveyor belts. These convey the material through a refrigerated tunnel whence in less than half an hour the solution emerges at the other end of the tunnel in the form of sheets of gel. The sheets are cut into strips by knives as they pass off the end of the belt.

In either case the cooled, solidified gel is immediately placed on screens or wire nets, with a mesh resembling that of "chicken wire" and usually made of aluminum or resistant alloys. These nets are fastened on wood frames. The loaded screens are piled on trucks, and the trucks are then removed to the drying tunnels where warm air at very high velocity is forced into the tunnel at one end by high speed fans and pulled out by suction fans at the other end. The trucks are moved along

slowly through the tunnel, countercurrent to the air, and in 16 to 30 hours emerge at the hot end. The gelatin now appears as thin transparent leaves which are stripped from the wire by means of whips. The wire is used to enable the largest possible surface area of the gelatin to be exposed, thereby enabling more rapid drying. The product is then mechanically broken into smaller pieces, ground, and mixed with other batches to meet the required specifications.

In another type of process the gelatin extract is not subjected to refrigeration but is placed in vacuum evaporators, then dehydrated to the form of flakes on the exterior of large horizontal drum driers which are heated internally by steam. The gelatin is dried during one revolution and scraped off by knife blades at the end of the cycle, which may require but a few minutes.

There is probably no food industry which requires more careful technical control of the processes than the making of gelatin. In addition to being a material which requires careful adjustment of hydrogen ion concentration during manufacture, the necessity of sanitary control is of primary importance. Microorganisms may cause lowering of quality and spoilage if the material is not rapidly chilled or dried during processing. In spite of the most rigid control during manufacture the characteristics of different batches of gelatin may vary somewhat and it is generally necessary to blend the product from different batches after the characteristics, such as gel strength, viscosity, acidity, etc., have been determined in the laboratory.

CHAPTER IX

FISH AND FISH PRODUCTS[1]

The fishing industry has harvested thousands of tons of foods from the waters of the world and gives promise of continuing to do so for some time to come. This industry has contributed a vast food supply, which is available not without hazards and hardship for those engaged in the industry, but on the whole without the constant and arduous labor necessary to plant, cultivate, and harvest crops or to care for the animals we use as sources of meat. The popularity of fish as food seems to be increasing somewhat in this country but is still far behind the important place it assumes in the diet of some of our European and Asiatic neighbors.

Recent years have seen a commendable increase in the utilization of the treasures of our waters, owing partly to a better knowledge of the types of edible fish and to improved methods of handling, transportation, refrigeration, and preparation for the ultimate consumer. Many people in the interior of this country are just learning how good some kinds of fish are as a food, because until recently no effort had been made to transport fresh ocean fish long distances inland under proper conditions.

Our grazing lands for cattle which were once so plentiful are being reduced in area each year by the encroaching increase in human population, although we have no immediate cause for worry in this respect. As a source of food supply our oceans and other bodies of water would probably have possibilities of much greater fish crops if an amount of care were to be devoted to fish culture equal to that which agricultural pursuits receive.

Many other countries, such as Japan and Norway, have a far greater respect for the importance of fisheries, because the limited extent of cultivated land available has for generations forced the population to depend on fish or plant products rather than beef as a source of protein which the human body must have.

Racial habits of our inhabitants have a considerable influence on the utilization of fish, as many of the descendants of immigrants follow the customs of their parents. Religious customs also play their part in relation to the consumption of fish, as Friday is always considered "fish day"

[1] The most comprehensive text on the subject of fisheries is Marine Products of Commerce, by Donald K. Tressler (Chemical Catalogue Company Inc., New York, 1923). The authors express their indebtedness to this source of information on which parts of this chapter are based.

and the Lenten season presents by far the greatest demand for fishery products. These same customs have caused many to gain the mistaken impression that fish as food is possibly inferior to, or at least less desirable than, meat. Another false notion which was fostered in the not far distant past was that eating fish often was an indication of poverty. Instead it is often an indication of good judgment.

Many types of fish now used as edible foods were once rejected because of prejudice, such as some of the sharks which now go under the name of grayfish when marketed. It also seems evident, at least in some parts of this country, that many otherwise good cooks are only vaguely familiar with the proper methods of cooking fish to make them most delectable.

Location.—Fisheries owe their locations to two important habits of fish; first, spawning, by many species of fish, in the shallow waters off the shore or in rivers; second, feeding in shallow waters known as banks, where the plankton is more abundant than in the deep sea.

Sea salmon come to maturity in the sea, but each year many go up fresh-water streams to spawning grounds where the females lay their eggs in the shallow water on clean gravel. Some kinds of salmon die after spawning. They are fat as they go up the river, however, and this is the time they are caught. The young smolts swim down the river into the ocean and become mature. After a number of years spent in the sea, the mature fish swims back up the same river, deposits its eggs and dies soon after. It becomes very thin on the trip up the river for it does not feed in fresh water and may travel hundreds of miles.

Quite the reverse of the salmon is the eel which lives in fresh water but goes to the distant parts of the sea in order to spawn. Once the eels go out to sea to spawn, they are never seen again. Hence, it is believed that they also die soon after spawning.[1]

Fish are prone to be found where there is abundance of food, where the temperature, and other conditions such as dissolved oxygen, salinity, lack of poisons, etc., are suitable. Most of the fish in the world come from the shallow-water areas which constitute some 10 million square miles of the earth's surface. Here are found most of the marine plants also, for the sunlight penetrates sufficiently to insure abundant growth of such forms. Since all animal life eventually depends upon plant life, there is much nourishment available, including almost limitless plankton, which supplies the smaller fishes with food. Larger fish feed upon worms, insect larvae, smaller fishes, etc. Thus the continental shelves of Europe and America furnish ideal grounds for fishing. The very much indented

[1] For an interesting account of such migrations see Fishes, Their Journeys and Migrations, by Louis Roole, translated by Conrad Elphinstone, W. W. Norton & Company Inc., New York, 1933.

coast aids. Many large rivers empty into the ocean carrying enormous quantities of food which may be used by the fish.

The great fisheries of the world are found in the North Temperate Zone between the fortieth and sixtieth parallels of latitude in the regions of relatively cold waters.[1]

The chief fishing grounds of Europe are the banks of the North Sea which are both extensive and productive, it being estimated that there are over 134,000 square miles of fishing grounds, with water averaging 50 fathoms in depth. The principal fish caught are anchovies, cod, haddock, halibut, herring, flounders, ling, plaice, sole, sprat, and whiting. The United Kingdom and Norway are particularly noted as fishing countries, both because of their large production of fish and fish products, and the greater consumption of fish by their inhabitants. Their fisheries furnish occupations for a considerable percentage of the inhabitants of these countries in contrast to the United States where it is estimated there were about 119,000 actually engaged in fishing out of a population of over 120 million (1931).

The United Kingdom is said to have a per capita consumption of fish of about 65 lb. per year, whereas the United States has been estimated by the Bureau of Fisheries to have a fish consumption of approximately 15 lb. per capita. In 1932 the United Kingdom exported 9 million dollars' worth of fish products but imported canned fish to the extent of 19 million dollars.

Norway is also a large exporter of fish, particularly of cod, herring, canned and salted fish, whale products, and cod-liver oil, the value of these exports in 1932 being about 30 million dollars. Denmark, including the Faroe Islands, Iceland, and Greenland, exported fish products to the extent of almost 7 million dollars in 1931. Japan is also noted for its large commercial fisheries, which are a major industry. The value of Japanese exports of fish and crab meat in 1932 was over 4 million dollars.

American Fisheries.—Of the North Atlantic fisheries, the Grand Banks off Newfoundland are undoubtedly the most famous and productive. Over a hundred years before the French made their first settlement in the Saint Lawrence Valley, vessels came over from France to fish in this region. Even at present the French send over fishing fleets which operate from the islands of St. Pierre and Miquelon as base stations where the fish are preserved by salting or are sold. The French have the right by treaty to land and dry their fish upon the shores of Newfoundland.

[1] For extended information concerning fisheries the reader is referred to the following:

TRESSLER, D. K., The Wealth of the Seas, The Century Company, New York, 1927.

GIBBS, W. E. S., The Fishing Industry, Sir Isaac Pitman & Sons, Ltd., London, 1922.

Cod is the most important fish caught on the Grand Banks, although haddock, halibut, hake, pollock, swordfish, and cusk are valuable components of the total catch. In 1933, Canada exported fishery products to the extent of 15 million dollars, of which about one-third were sent to the United States.

The Grand Banks harbor many dangers. It is an extremely foggy region much of the time, storms are violent, icebergs frequent the waters, great numbers of fishing craft are about, and the region is in the path of transatlantic ocean vessels. Nova Scotia, which catches about one-third of the fish produced by Canada has conditions much like Newfoundland but slightly warmer water.

New England Fisheries.—The principal banks or ocean fisheries of New England are Georges Bank, Brown's Bank, and the South Channel, although some of the New England boats get part of their catch on the Grand Banks. The Georges Bank, which furnished 39 per cent of the 1931 catch of the New England[1] fisheries, is located about a hundred miles east of Cape Cod. Brown's Bank is some 60 miles north and east of Georges Bank. South Channel lies between Nantucket and Cape Cod. In the same year (1931) Brown's Bank, which has an area about one-third that of the Georges Bank, produced 15 per cent of the total New England catch. The water on these banks is comparatively shallow and averages about 150 ft. in depth. Cod, haddock, halibut, hake, pollock, and cusk are the more important fish caught on the banks, and a large part of the fishing fleet is made up of vessels from Boston and Gloucester.

Those fisheries of New England together with the banks mentioned above, furnished the amounts of fish in recent years as shown in Table 69.

Table 69, showing the comparative value of fresh-fish products and salted products, indicates that for New England the most important commercial fish is now the haddock. In earlier days the cod was more important. The revenue from cod is of considerable magnitude and ranks second in importance. The value of salt fish landed (which is not the value of salt fish produced in New England as much fish is salted on shore, particularly at Gloucester) is comparatively small when one recalls that in the last century a large part of the fishing fleet in this region was primarily engaged in catching and salting fish and bringing their catch into port split and salted. The replacement of the old sailing vessels by steam and engine-equipped boats has lessened the necessity for such long trips, which made it essential to salt fish in order to preserve them before landing. The comparatively higher prices usually obtained for fresh fish have also caused a general reduction in the salt-fish industry.

[1] For a complete description of New England fishes, see H. B. Bigelow and W. W. Welch, Fishes of the Gulf of Maine, *Bureau of Fisheries Document* No. 965, 1935.

The recent introduction of filleting fresh fish and the shipment of fish fillets (fish flesh from which all bones, skeletal structure, skin, and detritus have been separated), has increased to a marked degree and created a special demand for haddock. The catch of haddock in 1935 in New England exceeded any previous year for which there are records.

TABLE 69.—LANDINGS AT NEW ENGLAND PORTS, 1930–1933

Fish	Value of fresh fish			
	1930	1931	1932	1933
Cod	2,100,433	$1,714,915	$1,267,720	$1,569,435
Haddock	6,645,786	,434,357	,906,808	,373,667
Hake	394,782	177,915	136,494	144,268
Pollock	263,740	113,714	85,600	158,814
Cusk	112,793	83,112	45,706	49,236
Halibut	442,397	375,836	261,154	226,026
Mackerel	1,154,408	,223,230	617,120	496,080
Flounders	651,410	450,865	295,517	376,509
Swordfish	725,949	458,745	356,933	305,989
Herring	11,431	8,496		655
Total, fresh	$12,503,129	$9,041,185	$5,974,041	$6,700,679
Total salted	170,772	126,732	55,521	96,132
Total fresh and salted	$12,673,901	$9,167,917	$6,029,562	$6,796,811

With the introduction of fish fillets there has developed a new method of merchandizing the product, as fillets can easily be packed in convenient packages, either for the retail store in units of 10, 20, or 30 lb., or for the consumer in 1- or 2-lb. packages. This system has also stimulated refrigeration, and particularly the "quick freezing" of packaged

TABLE 70.—PRODUCTION OF FRESH AND FROZEN PACKAGED FISH IN UNITED STATES, 1933

State	Pounds	Value
Maine	1,001,762	$ 162,149
Massachusetts	47,932,995	4,637,399
New York	5,300,307	763,408
Pennsylvania	305,791	62,911
Virginia and North Carolina	214,800	29,133
Florida and Alabama	325,300	39,251
Ohio	2,079,221	388,056
Illinois	1,199,161	247,838
Wisconsin	117,500	23,615
Washington	406,911	55,945

fish, many of which are frozen in the package, and which has made great advances in the past decade. Table 70 indicates the extent to which this industry has become important in Massachusetts, where haddock is the principal fish packaged.

Considerable quantities of packaged fresh filleted fish are now shipped with success in heavy-paper cartons, containing solid carbon dioxide ice as a refrigerant. The carbon dioxide ice is used in amounts ample to maintain low temperature but not sufficient to freeze the fish. Shipments of fresh fish may be made in this manner to distant inland cities the people of which formerly were almost unfamiliar with the taste of high quality, really "fresh" sea fish. At the same time this method of shipment avoids the freight charges of ice and heavy barrels or kegs, formerly needed as shipping containers, the weight of fish heads and unusable skeletal structures which are eventually discarded, as well as the handling of dripping and bulky containers. The development of such methods will be of greater benefit to the industry as time goes on.

In the Middle Atlantic States the shellfish are fish products of primary importance. Although menhaden are caught in tremendous quantities, they are low in value, as this fish is not used for food purposes, its high oil content being expressed for other commercial products. Haddock and cod are of less importance than is the case in the New England fisheries, and are exceeded both in poundage and value by flounders and squeteague, as shown below (Table 71).

TABLE 71.—FISHERIES OF THE MIDDLE ATLANTIC STATES, 1932

Species	Pounds	Value
Oysters (fall)	15,026,476	$1,763,506
Clams (hard)	3,955,632	441,128
Flounders	10,376,231	310,698
"Sea trout" or squeteague	9,087,563	210,859
Haddock	7,612,905	206,841
Cod	7,481 399	175,529
Lobsters	878,261	165,675
Bluefish	4,767,278	162,607
Butterfish	3,862,106	142,550
Menhaden	43,194,087	73,040

The main fish taken in the Chesapeake Bay (Maryland and Virginia) fisheries are menhaden, shad, croakers, alewives, squeteagues, and bass, with the shellfish, particularly oysters and crabs, assuming about twice the value of the sea fish.

The South Atlantic and Gulf fisheries, including North and South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas,

have as their more important food fishes snappers, squeteague, shad, mullet, kingfish and catfish. From the standpoint of value, the shellfish were more important than the other fish in the majority of these states. Shrimp are by far the most important shellfish products with oysters and crabs following in descending importance.

TABLE 72.—FISHERIES OF THE SOUTH ATLANTIC AND GULF STATES, 1931

States	Fish		Shellfish, etc.	
	Pounds	Dollars	Pounds	Dollars
Maryland.....	16,369,929	$ 526,837	50,263,900	$2,178,995
Virginia.......	170,042,156	,345,092	56,594,761	2,377,036
North Carolina	93,332,707	828,700	4,828,611	258,858
South Carolina	630,924	57,295	5,205,988	154,162
Georgia.......	1,351,042	55,185	5,998,771	195,953
Florida........	61,264,350	,902,082	22,789,496	1,691,380
Alabama	2,842,702	127,026	3,325,098	95,746
Mississippi....	1,372,865	49,452	21,612,457	545,921
Louisiana......	1,810,321	102,310	43,893,320	1,228,024
Texas.........	4,204,689	271,302	14,846,160	518,538
Total.......	353,221,685	$6,265,281	229,358,562	$9,244,613

The Pacific fisheries have salmon as their most important product. Although salmon are usually caught in smaller quantities than the pilchard or sardine, their products nevertheless have greater value. Other fish taken along the coasts of the Pacific States in considerable quantities are halibut, tuna, mackerel, flounder, steel-head trout, and bass. Shellfish are also an important product in these states. The salmon, with a value of almost 9 million dollars in 1931, comprised 50 per cent of the total fish production for California, Oregon, and Washington, which amounted to about 18 million dollars. Shellfish, of which oysters, clams, crabs, and shrimp were most important, contributed an additional value of nearly 2 million dollars during the same season.

The fisheries of Alaska are famed for the quantity and quality of the salmon obtained in this region each year. The annual value of the fisheries products taken in Alaska each year amount to more than the purchase price of the whole territory which the United States paid in 1867. In 1933 the estimated value of the salmon catch of Alaska was about 9 million dollars, while the value of the canned salmon produced was approximately 28 million dollars. Other products of Alaskan fisheries are herring, halibut, cod, trout, flounders, shellfish, and whales, although their total value is insignificant in comparison with salmon.

The Great Lakes of the United States are also the source of many valuable fish food products which yielded a catch in 1931 valued at over 6 million dollars and gave employment to about 7,000 fishermen. Herring were caught in largest quantities, with blue pike, lake trout, yellow perch, white fish, yellow pike, mullet, and chubs among the more important species taken.

The waters of the Mississippi River and its tributaries supplied food fish to the value of over 2 million dollars in the same year.

Methods of Fishing.—There are many methods of fishing depending on the species sought, location, etc., but the majority of those now used have been handed down through many centuries. The use of spears, traps, and lines with relatively few improvements have proved to be important means of capture even to the present time. Certain practices, such as the use of dynamite, are legally prohibited because of the extensive damage caused thereby. Under the various kinds of gear may be listed purse and drag nets (seines); gill nets; trammel nets; pound nets; fyke nets; dip nets; cast nets; push nets; bow nets; hand and trawl lines; wheels; weirs; otter trawls; traps of different nature; dredges; tongs; rakes and spears, according to Tressler.[1] The otter trawl, one of the most important developments in fishing gear, has attained considerable usage on the North Atlantic coast in recent years.

Fishing by means of seines is the most important method employed in this country. According to Radcliffe, about 30 per cent of the catch of the United States is made by seines. There are two different types of seines, the purse seine and the drag, hand, or beach seine. Seines are generally rectangular in shape, with cork floats attached to a line on the upper portion of the net to keep it afloat and lead weights on the lower end of the net to make it form a vertical barrier when launched.

The purse seine is used for surface fish and may be 325 yd. long and some 20 yd. in depth. The usual mesh for sea fish is 1.75 in. but may be varied according to the fish. Corks or buoys are attached at close intervals to the cork line which passes along the top of the net, thereby keeping the top of the net at the surface. Similarly, there is a lead line running along the bottom of the net to which are secured lead sinkers. Brass rings are suspended at intervals up to 10 yd. from loops attached to the bottom part of the net. Through these brass rings runs a purse line. When a school of fish is sighted, a seine boat and a dory are put out from the fishing vessel. The dory buoys one end of the seine, while the seine boat pays out the remainder of the seine as it is being towed around the school by the fishing vessel. After the two ends of the seine

[1] The best source of information regarding the fisheries of the United States is Marine Products of Commerce, by DONALD K. TRESSLER, Chemical Catalog Company, Inc., New York, 1923.

are brought together, a weight, or tow, is dropped overboard to help hold the ends of the seine at their proper depth, preparatory to its pursing. If all goes well, the school of fish has been encircled before many of them have had a chance to escape. In order to facilitate unloading, the fish

TABLE 73.—LANDINGS BY FISHING VESSELS AT PRINCIPAL NEW ENGLAND PORTS, 1933
(Pounds)

Species	Boston	Gloucester	Portland	Total
Haddock fresh:				
Large	,353,894	2,465,674	3,963,564	96,783,132
Scrod	,531,860	89,805	442,460	33,064,125
Haddock, salted:				
Large	400		9,900	10,300
Scrod		2,450	1,615	4,065
Cod, fresh:				
Large	,961,973	5,534,610	2,206,728	35,703,311
Market	,025,829	1,304,473	773,912	35,104,214
Scrod	195,945	16,210	18,863	231,018
Cod, salted:				
Large	50,500	1,533,428	61,106	1,645,034
Market	15,500	893,699	13,325	922,524
Scrod		235,677		235,677
Mackerel, fresh	,348,117	3,980,544	1,011,928	22,340,589
Mackerel, salted	9,800	56,000	38,100	103,900
Pollock, fresh	,261,580	3,398,112	735,515	12,395,207
Pollock, salted	50	90		140
Flounders, fresh	,278,542	376,910	583,031	10,238,483
Hake, fresh:				
Large	,683,613	476,042	637,031	5,796,686
Small	537,645	11,803	847,393	1,396,843
Hake, salted, large		1,355	1,675	3,030
Small				
Cusk, fresh	,498,576	278,865	651,171	3,428,612
Cusk, salted	....	1,384	330	1,714
Halibut, fresh	,755,664	4,280	376,628	2,136,572
Halibut, salted		130	1,985	2,115
Swordfish, fresh	,681,304	771	155,839	1,837,914
Herring, fresh	4,105	11,500	143,000	158,605
Herring, salted		703,494		703,494

are concentrated in one portion of the net by drawing in one side. The fish, if they have been entrapped successfully, are bailed onto the deck of the vessel which has by this time come up alongside the seine.

Haul, drag, and beach seines are used in shallow water, as a rule in rivers, lakes, or near the coast. The size and nature of these seines differ exceedingly. Some are only a few feet long, while others may be over a

mile in length. The meshes range from a fraction of an inch up to several inches, according to the kind of fish for which the net is designed. Seines may be rectangular but nets which are wider in the middle and narrowed at the ends are more common. Quite frequently there is a bag-shaped arrangement at the center of the net, with the meshes closed, which serves as a trap for the fish. On the end of the wings there are brails which hold the cork line and lead line in their positions and to which the drag or hauling lines are secured.

To catch the fish, the nets may be launched in several ways. One way is to lay the net parallel to the shore, then pull the net in by means of lines attached to the wings. Fish are caught and held by the folds of the net, being completely surrounded. The nets will hold any kind of fish, which are too large to swim through the meshes. One end of the net is sometimes made fast to a stake driven into the shore. The other end is swung around so as to form a semicircle. Since the shore end of this net is not so wide as the stream end, it is drawn in first.

The gill net is built much like the seines, but the size of the mesh is regulated by the size of the fish for which the net is constructed. The gill net forms a trap for fish which start to go through the net, but only their heads can pass the mesh. Their bodies are stopped and they become entangled by their gills in the netting. Since fish struggle considerably when caught, it is necessary for the netting to be strong. Linen or cotton thread is employed in net-making. To remove the fish from their traps, the net is pulled into the boat over a set of rollers. The bottom of the net is weighted with lead and the top floated by means of cork or other material, to keep the net upright. Gill nets may be set at different levels in the water. If it is desirable to catch demersal fishes (deep-water fishes) such as cod or haddock, the nets are laid near the bottom. They may be staked in position or allowed to drift with the current.

The trammel net does not differ greatly from the gill net. In place of the single net, there are three nets, the outer two having a larger sized mesh than the center one. Fish swim into the net, striking the close web which is forced out between the meshes of the outside web, forming a baglike trap from which it is difficult for the fish to get away.

There are many varieties of the pound net, but essentially it consists of three parts, the leader, the heart, and the crib. The leader is a fence of netting leading from the shore out into deeper water. It is constructed of stakes driven into the ground, from which the net is hung with the purpose of deflecting the fish into the heart. The heart, which is heart-shaped as a rule, is so built that the fish swimming within cannot find the opening to the outside because the sides of the heart are inclined away from the opening. From this blind trap, the fishes find their way into the crib or pot. The crib is usually a rectangular affair having mesh of

netting smaller than that of the leader. Upon the bottom of the crib is a net which prevents the fish from escaping below which is used also to lift the fishes from the crib.

Fyke nets are long baglike nets with the opening supported by a series of large hoops, the largest one being on the outside. Generally the hoops are not more than 6 ft. in diameter and the number from two up to a dozen or more. These nets are used for fresh-water fishing chiefly, and may have wings to guide the fish in.

Dip nets are small hand affairs by which the fisherman scoops the fish out of the water. They are used in streams and are particularly effective in fishing for salmon during their migration.

Fishing by means of lines and hooks is still a very important method, and is used for the ground fish, such as cod, haddock, and halibut. Instead of single hooks and lines, the so-called line trawls are now used almost exclusively. Some of the line trawls used in this type of fishing may be as much as 7 miles long.[1]

At intervals along the main or ground lines, short lines about 2 ft. long, branch off which are known as snood or gangings. On the ends of these are attached baited hooks. There is usually one snood every 2 to 5 ft. These lines are launched into the sea with an anchor and a float or buoy at each end of the line to mark its position. The line is left for a few hours or longer and later inspected. The fish are removed from the hooks as the line is drawn in. When fishing is good, the line is permitted to stay in the water and the fish are taken off by means of a man in a small boat, or dory. This man rows along and pulls the line in over his boat, removing the fish from the hooks (throwing the fish overboard, if they are of an undesirable kind) and rebaiting the hooks. This method is particularly good for deep-water fish, such as the cod.

The use of hand lines is still pursued. Men go out in small dories and fish from several lines. Each line contains two or three hooks and a sinker. Fish obtained in this manner are considered of better quality than those caught on trawls.

The otter trawl is a large conical bag-shaped net which is dragged along the surface, intermediate depths, and bottom of the water at the rate of 2 or 3 miles per hour. Its principal use is for the catching of the deep-water fishes, such as the cod, haddock, halibut, and plaice, but many herring are caught with it. Fishing by this method is called trawling.

The bag is large, sometimes over 100 ft. wide at the mouth and over 100 ft. long. A typical otter trawl is 70 ft. wide at the mouth and 110 ft. long. Two heavy lines known as warps extend from the vessel back to the otter plates, likewise two in number. Upon each side of the mouth

[1] Gibbs, W. E., The Fishing Industry, Sir Isaac Pitman & Sons, Ltd., London, 1922.

of the net there is one of these otter boards, the purpose of which is to keep the mouth of the net open. The boards are 10 ft. or more in length and 4 or more feet wide, and iron-shod to prevent wear and tear from contact with rough bottoms. When the vessel pulls on the warps the effect is quite similar to that experienced by a kite as one runs into the wind. The boards spring outward, opening wide the mouth of the net. The otter boards are attached to the net by the heavy lines running across the top and the bottom edges of the mouth, known respectively as the "head" rope and the "foot" rope. The foot rope is the heavier and longer of the two, and very often it is equipped with wooden rollers to assist it over the rough bottom. It is to these ropes, head and bottom, that the net is attached. Thus the upper portion of the net overlaps, or advances through the water ahead of the lower or bottom portion. The mesh on the outer part of the net is the wider, measuring in the neighborhood of 3 in., while that at the center of the net, or cod end, is 1 in. or slightly more, in size. The distance that the net is dragged behind the ship is dependent upon the depth of the water. It is customary to employ warps of a length about three times the depth of the fishing waters.

Weirs are a primitive form of trap used in rivers, lakes, or on the coast. As a rule, the weir consists of a leader which deflects the fish into a circular or heart-shaped enclosure. Brush is woven horizontally between the stakes and posts which form the weir, making it impenetrable by the fish once they have entered. It is possible for some of them to swim out through the opening of the trap, but very few do, for the sides of the trap next to the opening are inclined toward the inside of the trap and the fish swimming around are shunted away. The weir is employed extensively to catch herring, which are used in the sardine industry. Since herring are often found in rapidly flowing channels, it is important to place the leader across the channel in order to secure good catches. Fishes are removed from the traps by means of small-sized purse seines.

Tongs are a type of fishing gear designed mainly for the taking of oysters. They are scissor-shaped and their length depends upon the depth of the water in which they are to be used; this is generally from 12 to 20 or more ft.[1] About 4 ft. from the bottom end of the tong, the handle hinges. To each of the hinged ends a toothed iron basket is hung. The baskets are about 3 ft. long and 10 in. wide. When drawn up, they fit together. Tongs are relatively cheap instruments and their use is confined principally to small or shallow bodies of water.

For speed in securing oysters, the dredge is employed. The hand dredge has a capacity of 2 bu. or more while the machine-operated ones

[1] TRESSLER, D. K., Marine Products of Commerce, The Chemical Catalog Company, Inc., New York, 1923.

hold as much as 30 bu. Briefly, the dredge consists of an iron framework to which is attached a blade with or without teeth, and a bag. Two iron isosceles triangles, united at their apexes and held apart at their bases, form the framework, with certain modifications. The base of the bottom triangle holds the blade and teeth, and to the back end of the blade is attached the lower part of the bag, which has iron washers. Since the upper part of the bag receives less rough treatment than the lower portion does as it is being dragged along the ocean bed, it is made of twine. The frame is supported by iron cross pieces at points where there is stress or strain. Dredges are pulled by hand or by the aid of some sort of machinery.

In digging clams, a digger, usually called a clam hoe, and similar to the type employed in digging potatoes, is used. The handle is quite short, however, being not more than 1½ or 2 ft. long. Common garden rakes with baskets attached on the back of the wire netting; basket rakes, long-handled affairs for use in deep water; and claw rakes, composed of a series of curved iron prongs, are, according to Tressler, the equipment of clam diggers in different localities.

Handling of Fish Aboard the Boats.—If fish are caught in small boats near the shore, the containers may be covered with a tarpaulin or some other protection, and delivered fresh within a few hours. They should be kept cool, however, and the use of ice is often necessary. Larger boats, out for several days or longer, must employ cracked ice or refrigeration to assist in preserving the fish. When some fish, such as mackerel, are to be frozen, it is the practice to ice them in the "round" condition without cutting. Many fish are subject to intestinal putrefaction unless gutted soon after being caught. Hence such fish are gutted and ice is packed in the belly cavity and around the fish to keep them in optimum condition. Among the fish which are gutted are the cod, haddock, halibut, lake trout and sea salmon. The heads are often left on the halibut and salmon to prevent leaching out from the cut surfaces.

Within recent years a comparatively small number of vessels have been built with mechanical-refrigeration facilities for keeping the fish in a perfect state of preservation until landed on the docks. From the standpoint of preservation this equipment is ideal, but it is expensive. The usual method is to pack the fish in ice in the hold of the vessel until it returns to port. They will keep satisfactorily a number of days if properly iced.

In the past it has been a common practice to unload fish from the boats and transfer them with the aid of forks or pughs. This custom might seem to be justified from a practical viewpoint in that it enables fishermen or handlers to move the fish with manual ease, but this practice should not be tolerated. Fish deteriorate much more quickly, owing to the entrance

of microorganisms through such wounds, the quality is lowered, and consequently the market value is less. The use of slower but less injurious methods would prevent such damage.

One progressive fishing concern in Boston has tried some experimental fishing trips with some of their vessels using no forks, but the practice is not used exclusively. On the Boston fish pier, which is the largest in the world, the ancient system of using forks is still in vogue, partly owing to the protests of workers who resent any elimination of manual labor by mechanical equipment.

Methods of Preserving Fish.—Fish is notable for the speed with which it decomposes when taken from the water. Breakdown of the fish tissue is due to autolysis, and to the activities of microorganisms, chief among which are the bacteria. Both types of action result in biochemical changes, chiefly of a putrefactive nature. After the fish dies a condition known as rigor mortis appears which stiffens the body of the fish as the result of the coagulation of certain proteins by acid. Rigor mortis is an indication of a fresh fish. Soon, however, the enzymes which ordinarily perform the body functions, such as digesting the food, begin to digest the tissues with which they are in contact. Rigor is eventually supplanted by softening and flabbiness. Enzyme action can be checked by the application of heat to destroy the enzymes, or cold to retard their action.

It is possible to freeze certain species of live fish in water, thaw the ice, and find that the fish is still living. This is because the fish is a "cold-blooded" animal, *i.e.*, it has no heat-regulating system. For this reason and the fact that the habitat of the fish is not naturally warm, the enzymes of the fish are accustomed to function at lower temperatures than those of warm-blooded animals. Consequently autolysis is rapid in fish at ordinary temperatures. Furthermore, the physical and chemical structures of the flesh of the fish are much different from those of mammals. Bacterial invasion is through the gills into the blood, from the slime of the skin on and between the scales, and by way of the intestinal tract. The skin of the land animal is fairly resistant to penetration and to desiccation, but such is not the case with the skin of the fish.

Fresh fish are preserved for short periods of time by being packed in ice, but this is only a temporary means and the quality of such products will be lowered after a few days. The chief means of preserving fish for longer periods of time are freezing, canning, salting, smoking, and drying. Sometimes two or more of the above methods are combined.

Freezing is in many respects an inhibition process, in that the spoilage microorganisms, although usually lowered in numbers, are far from being eliminated. When the product is returned to higher temperatures, very definite deteriorative changes will occur, and some may even take place at storage temperatures lower than the freezing point of water. Enzyme

changes as indicated above may also take place which are the result of of enzymes inherent in fish tissues.[1] These changes are very much slower in freezing temperatures, but may be apparent after a number of months even at 10°F. storage.[2]

Drying is used to preserve fish because it is possible to lower the moisture content sufficiently so that microorganisms are inhibited. With the return of moisture, conditions are again favorable to the progress of deteriorative changes, however.

Salting is often combined with drying and is itself a means of drying or water removal from the fish tissues. Salting is combined with smoking for the preservation of a number of important fish products, particularly herring. Smoking is likewise generally accompanied by drying as it is difficult to separate the desired smoke from the heat simultaneously generated in burning wood. In the curing of meats some salt companies have prepared curing materials which produce a smoked flavor in salted products but the preserving action is due to the salt and other curing agents included in the mixture. This type of material is not commonly used for fish, however.

The canning of fish is a means of preservation depending on the heat treatment of the product in hermetically sealed containers. It may also be used as a means of preservation of fish products which have been previously subjected to some salting or smoking operations.

Chemical Composition of Fish.—The chemical composition of fish varies to a considerable degree, as shown by the following analyses by

TABLE 74.—CHEMICAL COMPOSITION OF FISHES (EDIBLE PORTION)
(Per cent)

Species	Water	Protein	Fat	Total carbohydrates	Ash
Salmon..	64	22	12.8		1.4
Cod.....	82	16.5	0.4		1.2
Haddock.	81.7	17.2	0.3		1.2
Mackerel	73.4	18.7	7.1		1.2
Herring..	72.5	19.5	7.1		1.5
Sardine..	52.3	23.0	19.7		5.6
Oyster...	86.9	6.2	1.2	3.7	2.0
Crab....	77.1	16.6	2.0	1.2	3.1
Clams...	85.8	8.6	1.0	2.0	2.6

Atwater and Bryant. The outstanding difference between certain of the fishes, such as salmon and herring, as contrasted with cod and haddock,

[1] NICKERSON and PROCTOR, *J. Bact.*, **30**, 383, 1935.

[2] See chapter on Refrigeration.

is in the large quantities of fat exhibited by the former types, which are among the so-called "fat" or oily fish. The quantities of fat or oil have a marked seasonal variation, which again varies according to the species. For example, mackerel caught in late summer are much richer in oil, whereas salmon have a higher oil content in spring or early summer at the start of the spawning season, and the fat content decreases thereafter. Protein is the most important food component of fish from the standpoint of the human dietary, and in dried fish of any kind the percentage of protein is increased markedly at the expense of the water which is removed in the drying operations. Dried bonito which has been dehydrated to the extent that it is more like stone than fish in appearance, is sometimes carried as a high-protein emergency ration in some Asiatic armies.

The shellfish, the composition of which is shown with the inedible portions, *i.e.*, the shells, removed, have certain amounts of carbohydrate present, usually in the form of glycogen, which is not found in the true fishes. The ash component of all salt-water fish is somewhat higher than that of most fresh-water fish or of many other foods, owing to the development of these foods in a saline medium. The presence of iodine, particularly in oysters, has been emphasized of late, because of increased knowledge regarding the necessity of this chemical element in the human dietary. Evidence has been presented to show that the oyster also has certain therapeutic values in the treatment of anemia, which it is believed are due to iron compounds.

Various oils obtained from fish have attained considerable prominence because of their vitamin content. Cod-liver oil, long a component of certain medicinals, has become an important product of the fisheries because of its high vitamin values, particularly vitamins A and D. Halibut- and swordfish-liver oils seem to be likely rivals in this respect, and according to the U. S. Bureau of Fisheries,[1] the burbot, a little known fish of the Great Lakes is especially rich in vitamins A and D.

The oils of the nonfatty fish are present almost entirely in the liver. Great care is now exercised in the gathering, storage, extraction, and purification of these oils because of their high market value. Tests for vitamin content are carried out biometrically with test animals.

Smoked Fish.—The preservation of fish by means of smoking is a very old and widely used method, but in importance it does not now compare with canning or freezing. Scotland has the leading smoked-fish industry, although many European countries, particularly Norway, Sweden, Russia, England, and Germany smoke large quantities of fish.

The following table from the U. S. Bureau of Fisheries shows some American data.

[1] *Annual Report,* Commission of Fisheries, United States, 1932.

TABLE 75.—PRODUCTION OF SMOKED FISH, NEW ENGLAND, 1928

Product	Pounds	Value
Alewives	145,770	$ 7,223
Finnan haddie	2,316,346	213,281
Halibut	20,656	6,281
Herring		
Bloaters	3,871,211	298,490
Lengthwise	125,490	8,347
Medium scale	544,907	66,932
Boneless	2,797,200	292,807
Kippered	131,475	22,465
Salmon	197,272	92,463
Fillets: cod and cusk	236,000	29,120
Fillets: haddock	634,147	109,493
Miscellaneous	606,978	125,607
Total	11,627,452	$1,272,509

It may be seen that of the various products smoked, herring was by far the most important as a total of 7,470,282 lb., or over 64 per cent of all the smoked fish or products, were herring. Finnan haddie (Findon haddock) was second, with slightly under 20 per cent of the total weight. Next in order come haddock fillets, cod and cusk fillets, salmon, alewives, and halibut.

Although in smoking fish the preservation is in reality largely by means of drying, thereby preventing the growth of microorganisms, there is also the deposition of the creosote ingredients on the product. These may include compounds containing phenols, creosols, guaiacol, etc. Action must also be ascribed to heat penetration, which may destroy the enzymes if the temperatures are sufficiently high and partially cook the flesh.

As a rule fish are salted for some time before being smoked. In the Orient, however, the preliminary salting is often omitted. Salting may be done either by the use of brine or by the dry salt method. It is customary to cut the flesh of large fish into strips previous to smoking, either removing the skin or leaving it intact. Evisceration is practiced on large fish and sometimes on well-fed small ones. The heads are usually removed and the fish split. Small fish are generally smoked round after washing and scaling.

There are two methods for smoking in common use, hot smoking and cold smoking. Hot smoking is employed chiefly in European countries. In this process the fish are placed very near the smoking fire and become partially or entirely cooked. But a few hours are required to smoke fish by this method. Cold smoking is the principal method employed in

this country and in Scotland, as well as some other European countries. In this process the fish are placed farther from the fire, so that the temperature does not go above 80°F. Exposure from a few hours up to a number of weeks may be necessary to smoke the product properly, according to the results desired.

In the smokehouses fires are built in special types of fireboxes or even on the earth floor. Small logs of hardwood are ignited by shavings or chips and after they are burning well, water-soaked birch, driftwood, hickory, or other wood, not containing resins, may be added. Resinous wood produces poor flavors. The main object is to employ wood which produces much smoke and burns slowly. Sawdust is frequently used in combination with other wood to secure these results.

Herring bloaters constitute one of the more important smoked fishery products. This is a product in which the raw fish is but lightly salted and smoked round. It must be consumed soon after its processing. Large herrings are used in the preparation of bloaters in this country. Fresh herring are subjected for two or three days to a strong brine and then washed. Herring which have been caught for some time and salted on board the ship are soaked in fresh water to remove some of the excess salt. The herring are then strung on sticks and exposed fairly close to the fire in the lower bays (or spaces) of the smokehouse. From 3 days up to a week is sufficient to give the light smoking desired.

Red or hard herring received its name from the fact that the fish are thoroughly salted and smoked until they are dry and hard. Fish caught at sea are immediately thrown into a vat of salt brine. All herring, whether freshly caught or brought in salted, are placed in vats in which there is some brine. A layer of fish is put in, then salt is spread over them, then another layer of fish, and more salt, and so on until the vat or butt is filled. Each layer of salt is a little heavier than the preceding one, the salt going into solution as it settles down. Formerly care was taken to remove the scales, but it was found that time spent on scaling was wasted, for the scales are efficiently removed during the handling which the fish ordinarily receive.

The salting process lasts from 1 to 2 days, depending upon the weather and the size of the fish. After the herring are thoroughly salted, they are taken from the vat and washed with brine or ocean water.

Next the herring are strung on strong slender sticks, pointed at one end, and a little over 3 ft. long. In stringing, the stringers lift the left gill cover up, insert the point of the stick through the gill slit, and then pass it through the mouth. Each stick holds about 25 herrings and is placed on a (rectangular) framework called a "herring horse." If the weather is clear the frame is put outside where the fish can drain and dry slightly; if not, the sticks are called at once to the smoke houses. It is

highly undesirable to fill a smokehouse completely with the salted herring, for the air would become saturated with moisture, which by condensing on the fish (due to cooling) might favor infection and spoilage by microorganisms. The sticks are placed on the lowest peg of the bay the first day, then a new lot replaces it on the second day while the first lot of herrings are moved up a peg. This procedure is repeated from day to day until the house is full—usually a period of about two weeks. The herring are then subjected to about three weeks more of smoking.

If the herring are to be boned, the heads, tails, and bellies are cut off with scissors.

A "kippered" herring is one which has been split from head to tail along the back, immersed in strong brine for about an hour, drained and slightly dried, and smoked for a number of hours. Kippered herring must be disposed of shortly or spoilage will result.

Finnan haddies are prepared by smoking haddock. The name is derived from Findon, Scotland, where they were first smoked, and from haddock. Findon haddock gradually became abbreviated to its present form. The head of the haddock is cut off, the back split down, and the fish eviscerated. A cut is made along the side of the backbone in order to help in the curing of heavy flesh on the back. After washing, the fish is immersed in strong brine for an hour or two. The fish are stretched out, nailed to strips, and the strips suspended in the smokehouse. Here after a preliminary drying for a few hours, a fire is made from oak wood and permitted to burn for nearly 18 hours. Sawdust is added to the fire and a dense smoke issues. After 6 hours of exposure to the dense smoke from the sawdust the fish are ready to be packed. This product must be stored at low temperature to avoid spoilage.

Salmon and halibut are smoked in a manner similar to herring. The strength of the brine, length of time of immersion of the fish in the brine, the preparation of the fish for drying, the way of butchering, and the kind of smoking vary.

The Drying of Fish.—The drying of fish in this country does not assume great magnitude outside New England, which produces salted and dried fish to the value of over a million dollars annually, but in the Orient, especially in Japan and China, the drying of fish reaches greater proportions. In Germany and certain other European countries fish are also dehydrated by mechanical means.

Dehydration is the drying of materials under carefully controlled conditions of temperature, relative humidity, and air velocity, and may follow a pretreatment of the product. Dehydrated fish are not usually sterile. The action of microorganisms is inhibited on account of the final low moisture content of the food. Enzyme action must generally be prevented by pretreatment, however.

Fish for drying are beheaded, eviscerated, scaled, and cleaned. If the fish is large, it may be skinned and cut up into smaller pieces and then exposed for drying on mats, stakes, flakes, etc. Drying requires several days, depending on size. The final product is not particularly appetizing, takes quite a little time to rehydrate, and does not have a pleasing appearance. However, in regions where animal food has a high value on account of very dense population and lack of agriculture, dried fish holds an important place in the diet. Fish may be pickled previous to drying.

Fatty fishes such as salmon and mackerel are not dehydrated as a rule, on account of difficulties encountered with the fat. The fat hardens in dehydration after the absorption of oxygen, which is undesirable.

FIG. 30.—Drying salt codfish. (*Food Industries.*)

It is advisable to store dehydrated fish in tight containers so the fish cannot rehydrate. Chemical reactions resulting from exposure to oxygen and sunlight should also be kept at a minimum. In this connection, the product might be packed in the atmosphere of an inert gas or in vacuum, but this is not practiced commercially.

Problems Associated with Oil in Fish.—Salted cod and haddock turn yellow and harden on account of the slight amount of fat within them. It has been ascertained that some enzymes within the blood of the fish are in part responsible for the yellowing and subsequent rancidity. Salts which contain much magnesium or calcium also accelerate this action. Hence, the careful cleaning of fish and the use of a high-grade salt do much to overcome this trouble.

Rancidity of the oil in fatty fish, such as herring, mackerel, and alewives is a chemical change accelerated by light, oxygen, heat, certain

metals, and other factors. The exclusion of oxygen by the use of hermetically sealed containers is one of the best methods of combating it. Storage under brine does much to prevent the appearance of rancidity. Rancidity is particularly a problem in smoked fish, especially in herring.

"Rust" is primarily an exudation of oil upon the surface of the fish, which is followed by oxidation and rancidity. It produces an objectionable appearance in the fish. The glazing of fish and the use of low temperatures for storage are helpful in minimizing rust. There may be oxidative changes and hydrolysis of the oil in fresh fish, but it is a slow process and is likely to pass unnoticed, unless the product is kept a considerable period.

Table 76 gives an indication not only of the relative value, but also the variety of canned fish products manufactured in this country. Salmon, tuna, and sardines are the more important products, although

TABLE 76.—UNITED STATES CANNED FISH PRODUCTS, 1932

Product	Number of plants	Pounds	Value
Salmon			
United States	35	31,414,080	$ 4,744,162
Alaska	87	252,216,432	21,715,918
Sardines			
Maine	13	13,642,425	1,370,050
California	19	45,791,088	2,358,399
Tuna and tunalike fishes	15	28,948,248	6,183,019
Alewives	3	567,360	24,950
Alewife roe	24	1,036,416	77,716
Shad roe	11	93,360	51,915
Mackerel	10	4,546,704	253,572
Fish flakes	5	602,496	104,575
Fish cakes, balls, etc	6	3,098,688	463,107
Cat and dog food	6	5,628,240	286,455
Salmon roe and caviar	5	205,824	28,166
Sturgeon caviar		121,968	330,149
Whitefish roe and caviar		43,008	34,047
Salmon eggs (for bait)		201,792	95,415
Misc. fish, roe, and caviar	16	485,040	60,054
Oysters	40	5,889,960	1,007,624
Shrimp	51	12,612,551	2,594,980
Clam products	63	8,376,870	1,797,002
Crabs	7	241,872	80,581
Turtle products	3	175,824	62,879
Misc. shellfish		122,160	24,447
Total	444	416,062,406	$43,749,182

among the shellfish, canned oysters and canned shrimp are products of high value. One more recent product is worthy of mention, namely, canned fish for cat and dog food which amounted to over a quarter of a million dollars in value.

The Canning of Salmon.—There are five species of salmon which are valuable for canning, the king salmon (chinook, quinet type or spring), the sockeye salmon (red or blueback), the silver salmon (coho or white), the pink salmon (humpback), and the dog salmon (chum). Of these species, king salmon is the most valuable and also the largest. Fish weighing as much as 100 lb. are caught, but the average weight is about 22 lb.[1] The flesh of this fish is usually a deep salmon red, but occasionally fish are caught which have white or mottled flesh.

The sockeye salmon is the greatest source of salmon for canning. Possessing a deep-red flesh and considerable oil, it is not only valuable from a nutritional point of view but also on account of its attractiveness. The average fish weighs about 5 lb., with individuals sometimes 12 lb. in weight.

Paleness of the flesh is a serious handicap to the sales of canned silver salmon, although the fish has a pleasing flavor. The fish averages about 6 lb. in weight, but some weigh 25 lb. or more.

Ranking next to the sockeye salmon in abundance, pink salmon is in high demand for canning. Its flesh is pale in color and also softer than that of the other species of salmon. Pink salmon is the smallest of the salmon (American species) used for canning since it averages about 4 lb., with a maximum of about 11 lb.

Dog salmon is the chief salmon in Japan. It is somewhat pale in color and when canned is soft or mushy. The amount canned depends upon the demand. Average fish weigh in the neighborhood of 8 lb., while some weigh fully twice as much. This fish can be preserved very well by other means, such as salting, smoking, or freezing.

Canning factories are located as near as possible to the source of the salmon supply, in order to save transportation and to procure the fish in a fresh condition. Since each of the five species of salmon has particular localities where it may be found most abundantly, the canner locates his plant according to the species which it is most desirable to can.

After the fish are brought to the cannery, they are allowed to stand for a few hours in order to permit some of the moisture to evaporate from them. The time allowed for this depends upon the species of the fish, the weather, and the temperature, there being a danger that certain species of fish will spoil more quickly than others. Fish are sorted into piles, containing the different species, then they are washed to remove

[1] Cobb, J. N., Canning of Fishery Products, Miller Freeman, Publisher, Seattle, 1919.

dirt and slime. After the preliminary washing, the salmon are ready to be dressed. Their heads and tails are removed by hand saws previous to their entry into the "iron chink." The fish go into this machine tail-end foremost and with their ventral aspects (or bellies) upward. A knife slits open the belly and the entrails are swept out with a brush. Immediately the fish are scaled, washed, and scraped as they pass through a tank of running water. Blood, offal, slime, and scales are removed.

The salmon are next cut by machine into pieces which will fit into the cans. These pieces are placed by other machines in the washed cans, and as the cans leave the filler, they pass over a weighing device, which shunts all cans not containing enough salmon off to one side, where workers, with a supply of small pieces of salmon, add enough to bring the can up to weight.

One-fourth of an ounce of salt is added to each can (containing 1 lb. of salmon). The cans of salmon are then exhausted at a temperature of 98 to 100°F. for a few minutes, depending upon the size and shape of the can. The cans are then capped, double-seamed, and washed to remove grease and other material.

Salmon are processed for a fairly long period, from 90 to 120 minutes, or longer for king salmon. The pressure of the retort is sufficient to produce a temperature of from 242 to 248°F. High temperature and a long time are necessary to soften the bones. The bones of the king salmon are larger than those of the other species, hence the longer time required for processing. Bones are rich in calcium and phosphate, and the fact that the bones of the fish can be canned means a large saving.

Generally the cans are washed again after processing, this time in a lye bath, and then a hot-water bath. It is necessary to cool the cans rapidly after processing to prevent a continuation of the cooking and the subsequent softening of the product. Salmon is packed with 48 one-pound cans to the case or 96 half-pound, or 24 two-pound cans.

Canned smoked salmon is quite a delicacy. The salmon is lightly salted in a salt brine for 8 to 12 hours, according to the size of the fish. (The fish are generally split down the back before pickling.) After removing from the brine, the flesh of the fish is smoked. Smoking is done in the upper part of the smokehouse as far away from the heat as possible and yet not in the bank of warm air at the top. This process continues for about 15 to 30 hours, depending upon the climatic conditions and the size of the fish. Salmon may be kippered likewise previous to canning. Following the smoking, the fish is cut up into pieces which will fit into the oblong cans or jars. It is customary to exhaust the cans and then to proceed as with other canned products.

The Canning of Sardines.—Sardines, as canned on the coast of Maine, are young or small herrings, while those canned in California are known

as pilchards. Since herring eat chiefly of two small crustaceans, *Schizopod crustaceans* and copepods, the latter being known as "red feed," a great deal of trouble is encountered in relation to canning these fish at times. The copepods decompose very quickly within the herring after it dies, with the consequent bursting of the herring's belly. Such herring are not in good form or condition for sale. This difficulty may be overcome in one or two ways, either by corraling the herring in water where they cannot obtain more food and permitting them an opportunity to digest the food already eaten before being canned, or by removing their viscera immediately upon being caught, a thing which it is often impossible to do.

The herring are caught by means of weirs, purse seines, or haul nets. Baskets operated by winches lift the sardines from the vessel to the cannery, which is generally situated over the water for sanitary reasons and for convenience in receiving the fish.

By means of sharp knives, or specially shaped scissors, workers cut off the heads of the sardines and remove the viscera. The fish are then collected and washed in water by drawing the net containing them back and forth through the water. After washing, the sardines are immersed in a strong salt brine for 20 to 60 minutes, the larger fish requiring the longer time, especially in cold weather.

The pickled sardines are next placed on flakes, preparatory to steaming. A flake is a rectangular frame about 3 by 2 ft., across which wires are strung, about 1 in. apart. As a rule five rows of the sardines are put on each flake. The loaded flakes are shoved into a horizontal retort and steamed for 10 to 15 minutes. Following this treatment, the flakes are removed to a drying room, where the sardines are dried by currents of warm air for 2 hours.

The dried sardines are placed in the familiar oblong cans and then submerged in a bath of oil at 240°F. for 4 minutes. Flavoring materials or spices are added if desired and the can is sealed. Cottonseed, peanut, or olive oils are sometimes employed as a packing medium, although in place of oil, mustard or tomato sauce, or vinegar with spices may be substituted. The mustard sauce contains mustard, cayenne, turmeric, and some other spices. Tomato sauce contains tomatoes, onions, salt, and spices.

The sealed cans go into a bath of water at 212°F. for at least 120 minutes, the largest cans remaining in the bath for 150 minutes. In place of this treatment, the retort may be used. After this treatment the cans are cooled and dried in sawdust and then tested for leaks. Lastly they are cleaned with sawdust.

Sardines are also prepared by frying in refined cottonseed oil after being dried as they come from the salt brine. They are then packed in

1-lb. cans with oil or sauce, sealed, and autoclaved. The method of frying the sardines is carried out chiefly in California.

Sardines may be smoked and dried before being canned. In France, the pilchards are dried, fried in oil, packed in the cans, and processed.

Fish Freezing.—During the height of the fishing season tremendous quantities of fish are caught which could not be readily disposed of as fresh fish within a limited period. The surplus is usually frozen, and for this purpose many of our fishing ports have refrigerating plants, or freezers, immediately at hand which are capable of freezing and storing vast quantities of fish or other materials which require cold for preservation. Some impression of the magnitude of the fish-freezing industry may be gained from Table 77 which indicates that in 1933 there were frozen more than 60 million pounds of fish of five varieties. The most outstanding increase in any type of fish frozen over the past 10 years is in the case of haddock, which in the form of fillets constitute a considerable part of the cod, hake, haddock, and pollock group. Frozen fish of this group increased from less than a 2-million-pound average up to 1925 to 23 million pounds in 1930. The use of refrigeration enables vast quantities of food to be preserved for supplying those periods of low production which must be expected in an industry with the uncertainty and highly seasonal nature of our larger fisheries. Without refrigeration the fisheries would be sadly handicapped.

The more common methods of fish freezing are discussed under refrigeration.

TABLE 77.—PRODUCTION OF CERTAIN SPECIES OF FROZEN FISH
(Pounds)

Year	Mackerel	Salmon and steelhead trout	Halibut	Whiting	Cod, hake, haddock and pollock
1920	4,835,173	7,836,620	10,625,029	10,208,955	3,940,163
1922	6,165,248	12,143,194	5,122,396	6,058,126	1,045,462
1924	5,457,676	14,309,666	14,650,787	7,528,339	1,862,163
1928	11,550,854	14,644,785	12,525,445	10,514,686	4,854,217
1929	11,301,474	12,441,339	14,083,230	8,834,081	11,179,959
1930	11,471,753	15,991,896	13,588,630	9,456,413	23,967,902
1931	12,352,336	13,010,488	12,979,692	7,911,144	15,774,783
1932	16,133,447	11,498,458	9,471,930	5,664,810	15,811,286
1933	10,535,000	11,726,000	13,881,000	7,286,000	18,564,050

New England headed the geographical sections of the United States in 1929 in the production of frozen fishery products.

Cod-liver Oil.—The term cod-liver oil is used to designate oil, obtained from the livers of codfish, which is to be used for human consump-

tion, particularly for medicinal purposes, in contrast to cod oil which is used for other purposes. The latter is generally of much lower quality though from the same general source, as the oil of this particular fish is found almost exclusively in the liver.

The fish from which cod-liver oil is obtained at present are usually eviscerated immediately after they are taken aboard the fishing vessels and the livers stored in barrels. In earlier days these livers were allowed to decompose until the bursting of the liver cells freed the oil, although such procedure resulted in a product of disagreeable taste and odor. Efforts are made at present to prevent such decomposition, usually by the use of refrigeration, as high temperatures accelerate those unfavorable changes due to bacterial and enzymic action.

The oil is obtained from the livers by rendering in steam-jacketed kettles or by the use of vacuum pans. It may also be accomplished by electrolytic methods. The use of vacuum is most favorable from the standpoint of color and flavor of the final product as lower temperatures may be used than is the case with open kettles.

After the heating is completed, the oil is cooled, sometimes to below 32°F., in order to solidify the stearin or fat which may then be easily separated from the oil by pressure filtration.

Cod-liver oil may be refined by treating it first with a solution of caustic soda, which forms soaps with the free fatty acids. The soaps, soluble in water, are removed by washing the oil with water. A dilute solution of sulphuric acid is finally added to neutralize any traces of alkali remaining. The oil is filtered through fuller's earth for color reduction and bleaching. Bleaching with oxidizing or reducing agents is likely to be destructive to the vitamin content of the cod-liver oil and therefore is avoided.

Cod-liver oil is one of the richer sources of the fat-soluble vitamins. Its use as a therapeutic agent in the treatment of rickets and allied diseases is widespread. It is particularly used in the diets of infants and children. In addition to the use of cod-liver oil for human beings, it is also used to a considerable extent as an ingredient of poultry foods, as a lack of the fat-soluble vitamins in the diets of poultry causes deficiency diseases in poultry also. In order to determine the vitamin potency of cod-liver oil, it must be subjected to a bio-assay or test by feeding to laboratory animals, usually white rats, under very definite and carefully conducted procedures.

Gloucester, Massachusetts, is the leading place for the production of cod-liver oil in this country. Some is produced in Maine, in the Western states—Washington, Oregon, and California—and in Alaska. Norway is a great producer of the oil. Lesser quantities are prepared in Iceland, Canada, Newfoundland, Scotland, and Japan.

TABLE 78.—UNITED STATES COD-LIVER OIL PRODUCTION

Year	Pounds
1928	1,873,085
1929	2,049,622
1930	1,179,971

UNITED STATES IMPORTS—QUANTITY AND VALUE OF COD-LIVER OIL

Year	Quantity, lb.	Value
1929	2,860,000	$2,445,000
1932	1,248,000	804,000

Recent investigations by the U. S. Bureau of Fisheries have shown that swordfish livers are a rich source of vitamins. Swordfish liver oil may contain 300,000 U.S.P. vitamin A units and 9,500 U.S.P. vitamin D units, or many times the standard minimum requirement for cod-liver oil which is 600 vitamin A units and 95 vitamin D units.[1] Halibut livers are also rich sources of vitamins and have attained considerable importance in this respect, and salmon oil also contains vitamins.

SHELLFISH PURIFICATION

Many of the shellfish areas of the United States have become subject to an increasing degree of pollution owing to the national habit of using rivers and harbors as vehicles for the disposal of sewage wastes from the communities bordering thereon. Such pollution, besides causing danger and damage in other ways, has become so great in certain districts that authorities have been obliged to prohibit the taking of shellfish for food purposes from extensive areas, because of the possibility of disease transmission through eating such shellfish.

Along the seacoast of the Middle Atlantic and New England states such conditions have been particularly prevalent owing to the presence of large centers of population near the ocean. In Massachusetts, conditions were such that considerable areas of productive clam flats were found badly polluted and digging of clams in those areas prohibited.

It is considered by many uninformed people that cooking shellfish, as in steamed clams, oyster, and clam stews, etc., renders them free from bacteria and eliminates the possibility of disease transmission. This is often far from the truth. Numerous scientific researches have demonstrated that clams, when cooked by the procedures commonly followed in the home, are not sterilized and generally are not heated sufficiently to kill nonspore-forming organisms such as *B. coli*, which are bacteria relatively susceptible to heat treatment. Cooking shellfish from sewage-contaminated areas may therefore create a false sense of security because

[1] *Annual Report* of the Secretary of Commerce, 1935, Bureau of Fisheries.

disease-producing organisms of intestinal origin may not be killed by such processes. In order to safeguard the health of potential users of shellfish from such areas and at the same time to enable the harvesting and marketing of such products which could not otherwise enter legitimate channels, methods have been devised which reduce the bacterial content of shellfish to such an extent that they may be eaten with relative safety.

Several treatment plants for the purification of clams have been in operation under state supervision in Massachusetts for about five years. In England a somewhat similar method is used for the purification of mussels.[1]

The clams from polluted areas are dug under the direction of authorized wardens or master diggers and are transported to the purification plant. Here the clams are picked over or culled, and all damaged or dead clams rejected. The shellfish are placed in ½-bu. boxes having wooden ends and wire-mesh sides and bottoms; then they are thoroughly hosed with chlorinated sea water. The boxes are then placed in concrete tanks of a size such that several hundred boxes may be treated simultaneously. When the boxes are placed, sea water is pumped into the tanks to a height of about a foot above the highest box. The sea water is then treated with a solution of sodium hypochlorite or it may be introduced into the sea water before filling the tank in sufficient quantities to sterilize the water. Usually an excess of hypochlorite is used in order to have a residual free chlorine content of 0.5 part per million. Thereafter, at intervals of 2 hours sufficient quantities of sodium hypochlorite are added, again to bring up the free chlorine to 0.3 to 0.4 part per million. This treatment is continued for at least 24 hours and must be continued for a longer period if the counts are not below 140. The water is usually changed after each 12-hour period and treated in the manner indicated above. Compressed air is liberated at intervals through orifices in the bottom of the tanks to supply oxygen for the metabolism of the clams.

Such establishments in Massachusetts are under the technical control of bacteriologists, who in turn are supervised and checked by the State Board of Health. Bacteriological counts for *B. coli* are made on the clams as they enter the plant, at the end of the 24-hour period and when the clams have completed the treatment if a longer time is used, according to the Standard Methods for Shellfish Examination adopted by the American Public Health Association.

Reports of laboratory findings in the treatment plants are required to be sent daily to the Department of Public Health and to the Supervisor of Marine Fisheries, as these two agencies share the supervision of this work in Massachusetts.[2]

[1] Dodgson, R. W., Report on Mussel Purification, *Fishing Invest.*, Series 2, vol. 10, No. 1, London, 1928.

[2] Wright, Edward, *Am. J. Public Health*, **23**, 266, 1933.

These methods have been used in Massachusetts with a considerable degree of satisfaction for several years. The following rules and regulations relative to the operations of plants for the treatment of shellfish were adopted by the Massachusetts Department of Public Health, March 8, 1932.

1. All shellfish treatment plants shall be kept under adequate supervision by a qualified chemist or bacteriologist at all times, and no shellfish shall be taken therefrom until passed by the person in charge after treatment as provided in the following rules and regulations:

2. The person in immediate charge of a shellfish chlorinating plant shall send a detailed description in writing to the Department of Public Health of all areas from which it is proposed to take shellfish for treatment purposes at least 1 week before shellfish are to be taken therefrom. Upon taking shellfish from a contaminated area under a written permit from the Supervisor of Marine Fisheries the person holding the said permit shall forthwith deliver the shellfish so taken to the person in charge of the treatment plant or his assistant and receive a receipt therefor either as to the quantity or weight, and as to the date and hour of delivery. Duplicate receipts shall be forwarded weekly to the Department of Public Health.

3. Storage compartments shall be provided for untreated shellfish, and all such shellfish shall be kept wholly separate from treated shellfish. The said compartments shall be under the supervision of the person in charge of the plant. A separate entrance shall be provided for the untreated shellfish. All shellfish shall be handled and stored under such conditions as will keep them alive.

4. All shellfish shall before treatment be thoroughly washed or hosed either with sterile sea water or water from some other source approved by the department, until all foreign matter is removed. All shellfish shall again after treatment be thoroughly washed or hosed with water taken from a source approved by the Department. In washing or dousing the shellfish in chlorinated water, the water shall contain throughout this process at least 0.5 p.p.m. of available chlorine.

5. All shellfish shall be thoroughly culled or inspected before filling the containers used for treatment purposes, and all shellfish shall again be thoroughly culled or inspected after treatment. All dead shellfish or shellfish in broken or cracked shells shall be destroyed.

6. Containers used in the treatment process shall be filled under the supervision of the person in immediate charge, and the containers shall not be filled with shellfish to a depth of more than 8 inches. In filling the containers a clearance of at least 1 inch shall be left between the upper layer of shellfish and the upper rim of the container. Containers used for treatment purposes shall not be used for any other purpose, and no containers or other equipment used on the flats shall be placed in the treatment tanks.

7. When shellfish are taken from several contaminated areas for treatment purposes, those taken from each separate area shall be treated in separate tanks and shall not be mixed with shellfish from other areas.

8. All water in shellfish treatment tanks shall be subjected to chlorine treatment, and no shellfish shall be passed until the same have been treated for at

least 24 hours, and for a longer period if the scores of the raw shellfish are 140 or over, in water which shall have been sterilized by chlorine and contain at least 0.5 p.p.m. of available chlorine 15 minutes after application, and the water shall be maintained in a reasonably sterile condition throughout the entire treatment period. Each treatment tank shall be filled with sea water from the usual source at least twice during the treatment period of each lot of shellfish. Determinations of the amount of dissolved oxygen in the water in the treatment tanks shall be made in order to ascertain that oxygen to the extent of at least 30 per cent of saturation is always present. Two or more samples of each lot of raw shellfish and four or more samples of each lot of treated shellfish shall be examined by the Standard Methods of the American Public Health Association for the determination of the B. coli score. Records containing the following information shall be available at the treatment plant at all times:

a. Area where shellfish were dug.
b. Quantity of shellfish in tank.
c. Time of starting treatment.
d. Time of ending treatment.
e. Scores of shellfish before treatment, as soon as available.
f. Scores of treated shellfish, as soon as available.
g. Time and quantities of chlorine applied.
h. Available chlorine determinations.
i. To whom sold.

No shellfish shall be removed from the treatment tanks until the 24-hour results of the untreated shellfish are read.

9. The results of the analyses of all samples, signed by the bacteriologist, shall be sent by mail to the Department of Public Health on each day that the plant is in operation.

10. Treatment plants shall be used for no purpose other than the handling of shellfish, and no shellfish from clean areas shall be handled at a shellfish treatment plant or by the management of such a plant. Material foreign to this particular business shall not be stored within the plant. No person not an employee of the shellfish treatment plant or a representative of the Department of Public Health or Department of Conservation shall be allowed access to the treatment plant or to the laboratory except by permission of the person in charge. All shellfish treatment plants shall be provided with suitable toilet facilities.

11. A portion of the plant may be used for shucking purposes, and the operation of this portion of the plant shall be under the supervision of the person in charge of the plant. Such a shucking plant shall be constructed and operated in general accordance with the U.S. Public Health Service Minimum Requirements for approval of State Shellfish Control Measures and Certifications for Shippers in Interstate Commerce.

12. Only clean containers shall be used for shipping treated shellfish in the shell. If bags are used for this purpose all such bags shall be sterilized before being used. Only non-returnable, clean containers shall be used for shipping shucked shellfish.

13. If the shellfish are shipped from the plant in the shell, the shipping containers shall be suitably sealed and marked as "Passed. ....shellfish

treatment plant." If the shellfish are shucked at the plant, the shipping containers shall be suitably sealed and marked as "Passed and Shucked .... shellfish treatment plant."

14. All other rules and regulations prepared by this department or by the Supervisor of Marine Fisheries of the Division of Fisheries and Game relative to shellfish shall be followed in the operation of all shellfish treatment plants. The Department reserves the right to change the above rules and regulations from time to time as occasion may require without notice.

OYSTERS

The oyster industry provides us with one of the most highly regarded and delectable foods of man, a tender, delicately flavored flesh, protected until ready for use by an extremely strong shell. The oyster was utilized by the Indians previous to the advent of the white man in America, and William Wood in his report on "New England's Prospect" written in 1634 cited the presence of a great oyster bank in the Charles River in Massachusetts which obstructed navigation. The Pilgrims found oysters and clams a valuable supplement to their often meager diet and used them in large quantities.

The popularity of oysters and the ease with which they could be obtained caused overfishing which has largely eliminated this bivalve north of Cape Cod on the Atlantic coast, except in Canadian waters. This same overzealous harvesting, together with the increase in industrial wastes in our streams which are often unfavorable for oysters has depleted many other beds. It is now necessary in many areas to propagate and cultivate oysters by a method which might be called undersea farming. The extent to which this is true may be gathered by the fact that in 1935 the United States Farm Credit Administration considered oyster growers in the same category as dry-land farmers and granted them loans as farmers.

The Atlantic and the Gulf states are the greatest oyster-producing areas and each year oysters to the extent of some 11 million bushels are taken in United States waters and provide a harvest having a value of approximately 5 million dollars to our fishing industry. The most important producing states are New York, New Jersey, Maryland, Virginia, Mississippi, Louisiana, although all our seaboard states produce some oysters.

The Atlantic oyster, *Ostrea virginica,* constitutes approximately 90 per cent of the oyster production in this country. The western native oyster, *Ostrea lurida,* constitutes somewhat less than 9 per cent of the crop, and the Japanese oyster, *Ostrea gigas* comprises the remainder. In Europe, where important oyster fisheries exist in France, England, Holland, Ireland and Italy, the European oyster *Ostrea edulis* is the common form.

Oysters are also an important fisheries product in Japan, China, India, and New South Wales.

The life cycle of the oyster makes it necessary for unusual procedures to be taken in order to insure a proper growth or set. The adult oyster discharges spawn during a period of two or more months, usually when the water has a temperature of 68 to 70°F. The very small larval forms resulting are unattached and free-swimming during their earliest existence and therefore are dependent in part on the tides for their distribution. Within a few days or weeks the larval forms increase in size and settle to the bottom where if a "set" is to take place, they must come in contact and then become firmly attached to some solid object. One of the problems of the oyster culturist is to provide materials on the water-covered beds which will serve this purpose, and thereby serve as anchors for the young oysters which at this state are called "spat." Many devices are used for this purpose. In some regions old oyster shells are distributed over the areas of the oyster beds, in some cases brush is coated with cement in order to provide large surface areas and even wire bags containing tiles, cardboard egg-crate partitions coated with lime, and similar objects have been used to serve as collectors. If conditions are favorable, the oyster may be harvested in a period two or five years later.

Many of the oyster waters are leased by individuals or companies who maintain the propagation of this undersea crop in those areas which they control, and later harvest them, eventually returning the shells for other oysters to develop upon. These shellfish grow best in waters of lowered salinity, *i.e.*, waters which are strictly representative of neither pure sea water nor fresh water, therefore the mouths of rivers, tidal estuaries, and similar bays and sounds make ideal locations for oyster farms. Those areas which have hard bottoms, rather than soft mud of silt, as a bed, are best suited for oyster propagation.

During its earlier stages the oyster is an easy prey to many aquatic enemies. Even after its shell has developed, it is subject to the depredations of the starfish, the oyster drill, and others. During recent years of the depression serious efforts have been made to lower the numbers of starfish which have caused such damage by paying bounties for the gathering of starfish by unemployed fishermen.

On the Atlantic coast where the oysters usually develop in beds which may be 30 ft. or more under water, they are harvested by means of dredges which are dragged by power boats. These dredges resemble large rakes in action, although the oysters are collected in the rear of the dredge which is made of rope meshes. Long tongs may be used in the more shallow waters. After the oysters are brought to shore, they may be iced and shipped at once as fresh oysters or they may be shucked or taken from the

shells in the oyster house at the shore. In the latter case it is essential that every precaution be taken to maintain sanitary conditions in the shucking plant to avoid contamination of the product which may result in disease, especially as oysters are commonly eaten without cooking. Many oysters are canned, particularly in the Southern areas far from large markets.

It is essential that oysters should be grown in waters which are free from sewage pollution, and very definite regulations have been imposed on the handling of oysters in order to insure that those subject to pollution are not used for food purposes. Both the waters in which the oysters are grown and the oysters themselves must meet bacteriological standards set up by state health departments within whose jurisdiction they are produced, and also by the United States Public Health Service if they enter interstate traffic.

It was in the past a rather common practice to transplant oysters, or to remove them from suspicious areas where they were subject to pollution, and to transfer them to other waters which were presumably clean and unpolluted. The storage of oysters in clean waters for periods of a few days, providing the temperature, salinity, and other conditions are conducive to active feeding, is believed to result in purification. River estuaries were used for this purpose in some states, but the practice has been recently prohibited.

Several large oyster-handling and -growing organizations have a system of conditioning oysters by placing the harvested oysters in large concrete tanks into which chlorinated sea water is pumped. This process tends to clean the oysters, provides storage, and is said to result in better keeping quality. Since the oysters so treated come originally from areas which are considered of satisfactory sanitary quality by health authorities, this process is not to be confused with the transplantation discussed previously. Its primary purpose is quality rather than safety, although the two can hardly be divorced.

The shipping of oysters has been subject to much attention because of the possibility of spoilage if the product is not properly refrigerated. Spoilage conditions are likewise those which favor the development of any pathogens which may have gained entrance. If ice is used for cooling purposes, it is kept from direct contact with the oysters to prevent dilution of the oysters by water, and also to eliminate the opportunity of contamination by bacteria. Some of the larger companies now pack their product in small household-size containers sealed at the plant which insure protection and quality to the consumer. Oysters are also packed in domestic-sized cartons and frozen.

The improvement in handling and transporting oysters has widened the zone of their marketing and utilization. Lemon reported in

1931[1] that St. Paul, Minnesota, used more fresh oysters per capita than any other of the 14 United States cities studied.

Recent research has indicated that the oyster has a high mineral content of iron, copper, manganese and iodine which are desirable in organic combination in the diets used for certain deficiency diseases, such as iodine for the proper functioning of the thyroid gland. The other three minerals are reputed to be helpful in case of nutritional anemia.[2,3] Oysters are also said to contain vitamins A, B, C, D, and G.

[1] LEMON, U. S. Bur. Fisheries, *Fishery Circ.* 3, 1936.
[2] PEASE, H. D., *J. Chem. Ed.*, **9**, 1675, 1932.
[3] WHIPPLE, D. V., and O. M. WOLF. *Am. J. Physiol.*, **97**, 569, 1931.

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Report of Committee on Standard Method for the Bacteriological Examination of Shellfish, *Am. J. Pub. Health*, **12**, 1922.

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CHAPTER X

POULTRY AND EGGS

POULTRY

Although there are few regions in this country which are devoted exclusively to the production of poultry, the magnitude of this industry is usually not appreciated. Every state and the majority of the farms in this country contribute to the poultry supply, and while the amounts produced per unit may seem small, the aggregate is very large. It is estimated that in the United States in 1931 there were over 450 million fowl of all ages, which in that same year produced some 31 billion eggs. As the flesh of these animals constitutes a considerable, and constantly increasing part of our food supply, the care used in its production and storage is of importance.

In contrast to the apparent decline in consumption of beef the per capita consumption of poultry appears to be on the increase, the per capital consumption rising from 18.0 lb. in 1920 to 24.1 lb. in the period from 1927–1931.

In addition to such poultry products as are produced and used in this country, there were imported in 1931 over 83 million pounds of egg products not-in-the-shell, *i.e.*, frozen or dried eggs, particularly from China.

The most important poultry production areas are in the states of the Corn Belt, where the farm flock is particularly prevalent owing to the availability of cheap food, although the raising of poultry as a side line is common throughout the country. Many rural homes and numerous city homes have their small flock of hens which produce flesh and eggs which augment the family larder and sometimes enable the sale of a small surplus in the near vicinity. Outside of many of the metropolitan areas may be found poultry growers whose sole income is derived from furnishing the city inhabitants with poultry and eggs. Roadside stands in the suburbs have sprung up which merchandise poultry and poultry products, along with other products of the farm, to those who pass their doors.

Poultry, in its broadest sense, includes domestic birds, alive or dressed, which have been bred and raised for eating purposes, egg production, or for show or exhibition purposes. Domestic birds generally include chickens, domestic fowl, ducks, geese, turkeys, and pigeons.

Chickens, including young and adult, are by far the most important, although very definite demand for geese, ducks, and turkeys exists in

certain districts. Turkeys are raised in large part for the holiday season, particularly for Thanksgiving and Christmas.

The following discussion of poultry will be confined largely to chickens and domestic fowl.

TABLE 79.—POULTRY AND EGG PRODUCTION IN UNITED STATES, 1933

State or section	Chickens (on hand), thousands	Chickens raised, thousands	produced, millions
North Atlantic.......	48,967	74,498	4,146
East North Central...	95,360	143,800	6,564
West North Central..	133,615	199,503	9,612
South Atlantic........	46,045	66,883	2,668
South Central........	93,869	119,768	5,256
Western.............	43,790	58,098	4,017
Iowa................	33,875	50,234	2,356
Missouri.............	28,320	37,853	2,024
Illinois..............	26,870	37,662	1,597
Total United States	461,646	662,550	31,813

The modern American hen owes her ancestry to fowls that originated in foreign countries. Early settlers in this country brought their first stocks from Europe on ships, as hens were unknown in the new land, although wild turkeys were common enough to start our present Thanksgiving customs. These European breeds are believed to have originated in India and to have become domesticated even before the Roman era. During the middle of the past century other Asiatic breeds were imported from China which gradually were bred with the common American types. The results led to the establishment of new standard breeds which are still popular. Of these, probably the Rhode Island Red, the Wyandotte, and the Plymouth Rock are most widely known. Others of importance are the White Leghorn, White and Buff Orpington, Jersey Black Giant, and Australorp breeds.

Much effort has been devoted to the selective breeding of poultry stock to develop the most desirable types, from the standpoint of both egg-laying and meat production. A number of the American breeds are dual-purpose birds, which combine favorable egg-laying capacity with a body structure which produces good flesh. Some of the smaller, more active varieties, such as the White Leghorns, are not so desirable from the flesh standpoint but more than compensate by their egg-laying capacities. Birds of a number of varieties have been demonstrated to produce eggs at the rate of almost one a day over periods of a year, and with eggs selling at a reasonable price, such hens are valuable machines from a producer's

standpoint. Just as dairy cattle have been chosen for their milk-producing abilities, the poultry man has selected his breeding stock to favor his desired qualities and perpetuate them in his flocks.

Representatives of types of poultry raised for meat alone are generally characterized by blocky bodies, fairly long and deep, full short legs, and a small amount of offal and bone. The flesh is soft and of good quality until the chicken is about a year old, when it tends to become coarse and fibrous. In male chickens (cockerels) the meat is best between the seventh and tenth months. The Brahmas, Cochins, Langshans, and Dorkings are good examples of breeds for edible purposes, and range between 7 and 12 lb. in weight at maturity. Fowl of these breeds lay but

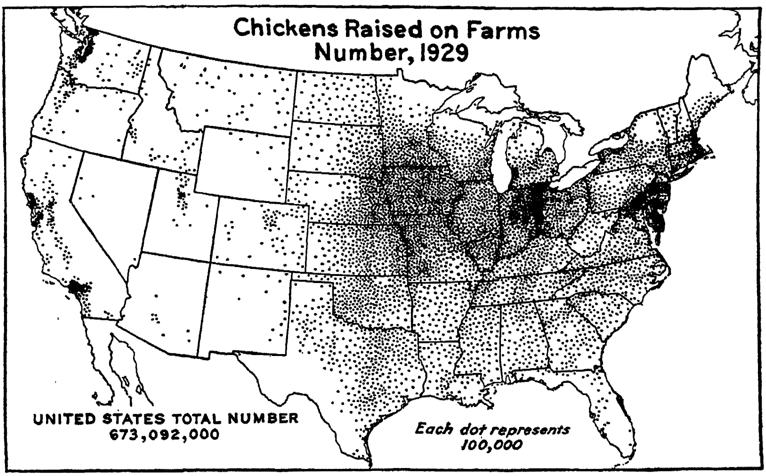


FIG. 31.—(*U. S. Dept. Agr.*)

few eggs and are inclined to be quite lazy, or sluggish in nature, factors which favor the production of tender muscles and abundant fat deposition.

Another type of poultry is that illustrated by the Rhode Island Red, Wyandotte, and Plymouth Rock breeds. These hens are good egg producers, of a rather quiet nature, and are useful for meat after they have passed the stage where they are profitable as egg layers. In build, these chickens are in general similar to the meat type described above, but they are about medium in size.

Smaller, more active breeds such as the Leghorns, Minorcas, Andalusians, Anconas, and Spanish are active egg producers and have small bodies which are relatively undesirable for meat purposes. Leghorns are by far the most important representative of this type and are particularly prevalent in those districts which are primarily concerned with egg production. The cockerels and nonproducing hens are sold for food purposes, however.

Capons, or castrated males, which sometimes attain extra size and weight, yet have tender flesh, are produced for the very choice markets.

The meat of poultry is fine-fibered and firm, and not mixed with fat as is the case with beef. The fat usually lies in layers under the skin, inside the body cavity, and around the intestines. Chickens and turkeys have much white meat, while geese and ducks are dark-meated birds. In general, the meat of fowls is pale in color, but red muscles may also be found. The odor and flavor of the flesh depend upon the species and its feeding. Poultry fed largely with oil seed, oil cake, or hempseed have an oily flavor. A fishy odor and taste come from feeding with fish.

The way in which poultry are fed a few weeks previous to their killing has a great deal to do with their market value. There are two common methods of feeding or fattening—the corn and the milk diets. Instead of corn, in the so-called corn feeding, other feeds may be used, as, for example, ground oats or barley, wheat middlings, beef scrap, and tallow. Corn has a tendency to produce a yellow skin and fat, owing to the carotinoid pigment. The fat may be deposited over the outside rather than in the muscles on the hips, back, or abdomen, just under the skin. Fat so deposited may be largely lost in cooking; it does not add or improve the keeping qualities and bruises show up easily due to the tender skin.

The milk feed may be made up of buttermilk, corn meal, and middlings (wheat). Skim milk, whole sweet, or sour milk may be used, depending upon its abundance and value. Poultry fed with milk mashes are superior products. Fat is formed close to the connective tissue and within muscle fibers, adding flavor and tenderness to the flesh. Furthermore, the skin and flesh of the milk-fed birds generally appear lighter in color and find preference in certain markets.

Haphazard feeding often results in poultry which may be deficient in muscle and fat, the skin may be thin and wrinkled, the flesh hard, and the bones protruding. The period of fattening lasts from one to three or four weeks, depending upon the conditions. In order to derive the greatest advantage from the special feeding period, the bird must have a strong appetite and must have practically no exercise.

Fattening may take place in a pen or in crate. Some poultry distributors maintain large buildings in metropolitan areas where thousands of birds may be caged and fed in "batteries" for the period of fattening. Usually crate-fed poultry are milk-fed. General cleanliness, freedom from overcrowding, good ventilation, and disinfection of the crates at least once a week, with immediate removal of trampled or diseased birds is essential. Previous to starting the fattening process, a fast of 24 hours, allowing only water, sometimes yields good results. Only as much food is offered as is entirely consumed. Just as soon as the birds go "off their feed" or lose their appetites they must be killed, for a loss in weight starts

at once, unless "cramming" is resorted to. "Cramming" is forced feeding. Food is administered to the poultry by means of the hand, a funnel, or special machine in this case.

Just before killing, the birds are often subjected to a fasting period. The prime object of fasting is to improve the tenderness and the keeping quality, the appearance, and flavor of the flesh. A bird when gorged, excited, fatigued, or overheated does not bleed well. The fasting period gives an opportunity to the bird to rid its digestive tract of material. An empty digestive tract is less likely to be the origin of bacteria which may eventually gain access to other tissues by passing through the intestinal walls. A full intestine does not drain easily and in preparing the carcass there is always a danger of breaking it and spreading the contents on the flesh.

Slaughtering Methods.—Beheading is one of the oldest methods practiced. It has several disadvantages, however. There is incomplete bleeding owing to a clotting of blood on the severed neck. After beheading, the bird flops around involuntarily, by reflex action, causing a spattering of the feathers with blood, and a bruising of the skin and tender flesh as hard objects are encountered. Some poultry is killed by wringing the neck. This also results in incomplete bleeding, the tissues and blood vessels are twisted and displaced and may prevent bleeding and clotting of the blood is promoted.

When a fowl is not properly bled, the neck turns red, then bluish red, and finally, greenish in color. Red dots on the wings and thighs, and the appearance of the veins near the angles of the wings are also an indication of improper bleeding.

One of the methods of killing poultry is by means of dislocation. The skull is separated from the neckbone at a distance of about 2 in. thus severing the jugular vein and the spinal cord. The bird is suspended to facilitate bleeding. Bleeding occurs in the pocket formed in the neck, and while not entirely complete, it is satisfactory. Clotting does not occur since there is no exposure to the air, but pressure is built up by the blood in the pocket, resulting in the absence of perfect bleeding. The neck of birds killed in this manner is large and discolored. Poultry killed in this manner may be dry-picked.

"Sticking" followed by debraining is considered to be perhaps the best method for killing poultry. In this method the bird is suspended head downward by means of shackles attached to its feet. A sharp knife is inserted into the mouth and across the base of the brain. It is drawn to the right, severing the jugular vein. Just as soon as blood starts to issue from the mouth, it is evident that the jugular has been successfully severed. Debraining immediately follows. The knife is inserted through the groove in the roof of the mouth, backward in a plane between the eyes

and ears, until the brain is reached. At this point, the bird generally squawks and flops. A twisting motion is given the knife to destroy the brain. Sometimes the jugular vein is severed from the outside of the neck, back of the ear. Then, too, the bird may be debrained first and the jugular vein cut afterward. A special kind of knife may be used in debraining, and it may be inserted from just under the eye, directly into the brain. (Cups for collecting the blood may be suspended from the bird's head.)

The killing room should be kept in a sanitary condition; feathers, blood, and ventings should be collected and properly disposed of frequently and regularly; ventilation and lighting should be adequate; and clean, pure water should be used in all operations.

By the kosher method, poultry are killed by rabbis or their representatives, in accordance with ancient Hebrew law. (Meat killed under strict observance of the Hebrew laws is known as kosher meat.) The bird to be killed must be free of disease and broken bones. A clean, sharp knife is used and the blade must not scratch as it cuts. In killing poultry, a few of the feathers are plucked from the throat and then an incision is made severing the trachea and jugular vein completely. Only one stroke is made, *i.e.*, the blade must not be inserted after having once been withdrawn. After cutting, one end of the trachea is pushed out through the opening to insure the fact that it has been cut in two. The birds are then thrown into metal cans to bleed. Kosher poultry is sold without being picked. At the market, the buyer, who often picks out the bird while it is still alive and waits for it to be killed, may hire someone to remove the feathers, which are not removed so cleanly as if the bird had been debrained; or he may take the bird home and do it himself.

Feathers are removed by dry picking or scalding. In dry picking, work commences just as soon as the tissues have relaxed. A picker, known as the "rougher," plucks most of the feathers from the neck, breast, shoulder, back, thigh, wings, and tail. Other workers complete the task, removing the pin feathers, generally with the help of knives. Poultry which have been dry-picked keep much longer than those which have been scalded. Birds which are to be put into cold storage or shipped a long distance are dry-picked.

In removing the feathers, care must be exercised not to tear the skin. A torn skin renders infection by bacteria easier, and injures the appearance of the bird. Feathers are removed by a twisting and sweeping movement of the hands.

If poultry are to be defeathered by the scalding method, they are allowed to lie until the muscles holding the feathers have relaxed. The birds are then held by the head and two feet and drawn through the scalding bath. The temperature of the bath varies from 150 to 190°F.

Too high a temperature results in tendering or cooking the skin, and when the feathers are then pulled, there is much danger of tearing the skin. Scalding loosens the feathers; it adds to the appearance of the bird by making it appear plump; and the yellow color of the skin is deepened and made more attractive. The disadvantages of scalding are that the hot water renders the skin penetrable to bacteria, some of the flavor is lost, and the keeping qualities are much reduced. A recently developed method which facilitates feather removal consists of dipping the bird in a hot rosin solution, then cooling, and stripping by hand.

Immediate cooling or chilling is necessary to prevent bacterial multiplication and enzymatic activity. Decomposition by either bacteria or enzymes hurts the flavor of poultry. There are two ways of chilling, the wet and dry methods. The wet method is an old and objectionable practice. The birds are thrown into ice water or spring water just as soon as they are scalded and picked. It requires 5 to 10 hours to chill the poultry, but as an additional period of time in the water causes the bird to become more plump (increased in weight and appearance), there is the tendency to leave the birds in the water for several hours longer than is necessary for chilling alone. This practice has the disadvantages common to leaving poultry in the scalding water too long—loss of protein material and flavor, the flesh is more easily penetrated by bacteria, and the keeping qualities are lessened.

In dry chilling, the poultry may be cooled naturally by cold air or artificially by means of refrigeration. The use of refrigeration is obviously more efficient because the conditions of cooling may be easily controlled and standardized. A temperature range of from 32 to 36°F. is satisfactory for this purpose. If the temperature is much below 32°F., heat does not escape readily from the interior of the bird on account of the production of a contracted condition on the outer portions of the bird which approaches insulation. This condition may be compared with that of "case hardening" in the dehydration of potatoes and other products. Ordinarily, a period of 10 to 24 hours, or longer, is required for the chilling process. Poultry to be chilled are hung by their feet in the refrigerated room so as not to be in contact, and to permit the free circulation of air about each. First, however, they may be hung up for 1 or 2 hours in the open to dissipate some of the body heat before being placed in the chilling room.

Poultry keeps best and is in the best condition if undrawn, *i.e.*, if the viscera are left intact in the body. Drawing exposes the bird to contamination. Singeing, the opening of the body at the neck and vent, exposure of the body cavity, and washing (if done) are all operations which favor bacterial infection. The intestines may be ruptured when drawn, with a scattering of the contents, rich in bacteria, over the flesh.

In case the intestines are broken, the body cavity must be thoroughly washed out with water. Even then the bacteria may be spread throughout the body cavity, although gross contamination may be reduced.

Singeing is for the purpose of removing the last small feathers and hairs from the body. The fuel used to supply the flame should be one which will not deposit smoke on the poultry.

Drawing may be full or partial. Full drawing implies removing all the contents of the body cavity, the head and neck, and the feet. The tendons from the rear of the shank are removed customarily, for in old poultry or roosters the flesh of the thighs is tough on account of them. The shank may be severed about one-half inch below the knee. Following this, the head is taken off, also the neck bone close to the shoulder, and the oil gland found at the upper base of the tail. An incision is made back of the neck near to the shoulder. Through this slit, that portion of the esophagus extending from the end of the neck to the crop, and the trachea are extracted. The crop is loosened along with the heart, lungs, liver, gizzard, and stomach, by means of the finger. This is done to facilitate their removal through the vent opening. Just above the vent a transverse incision is made. Through this incision, a finger is inserted to grasp the large intestine and hold it while a small, circular opening is cut around the vent. Before extracting the various organs which include the heart, lungs, liver, intestines, gizzard, crop, esophagus, and sexual organs, they are loosened from the body cavity. If care is used and the bird has been starved previous to killing, there should be no difficulty in removing the various organs without breaking any of them. In case, however, the bird has not fasted for 24 hours, and the intestines are full of food, they may break, in which case it becomes necessary to wash out the body cavity with clean water. Under no conditions should the cavity be washed unless a rupture has occurred, since rapid deterioration is likely to result from this practice.

As a rule, the heart, liver, neckbone, and gizzard are included with the drawn poultry as it is sold. The gizzard is first cleaned by removing from it the grit sac and food material. Some people use also the feet, the head and comb, and lungs.

Broilers are drawn differently. The head is cut off, and the back split along one or both sides of the backbone, and the body cavity opened. The viscera are completely removed. In case incisions are made along both sides of the backbone, the backbone is lifted out.

Ice Packing.—Birds which have been scalded or wet chilled are generally packed in ice in barrels. Crushed ice is packed carefully around the crops and vents and between the layers. A cake of ice may be placed over the top layer to insure low temperature. Burlap is placed over the top of the barrel and held in place by the top hoop.

Dry Packing.—If poultry has been dry-picked or dry-chilled, it is packed in boxes, kegs, or barrels without ice. Barrels were the common containers a few years ago, but they have been replaced in present practice by boxes. The barrel held 200 to 250 lb. of poultry, but there were marked disadvantages in its use. Birds so packed were inclined to lose their shape; there was inevitably some heating, discoloration, and deterioration on account of the weight and close packing; birds at the bottom of the barrel could not be inspected until all those on top had been removed; the barrel was heavy to handle. Later a keg was employed by some packers instead of the barrel. The keg held less than the barrel and was handier, but never became popular. Then came boxes, with the packing of birds in two layers. Finally, the one layer box was evolved. In this container there is sufficient room for air circulation, the birds do not press heavily against each other, and there is room for attractive packing. A box holding 12 birds can be easily handled, inspected by merely knocking a board or two from the top, and can be cooled properly, and kept in excellent condition. Boxes are made from light-colored, light-weight wood, which is strong and free from odors. Parchment paper is used to line the boxes. In packing, the heads of the birds are wrapped in paper, and folded back in such a way as not to come in contact with the flesh.

Shipping.—If the distance which the poultry is to be shipped is fairly long, refrigerated cars should be used, with a temperature of 31°F. or below. It requires about three weeks to market poultry which has been chilled. A rise in temperature above 31°F. results in marked decrease in the number of days which the poultry will keep in good condition. The flesh and especially the skin of birds is not sterile, and the bacteria will multiply rapidly unless destroyed or inhibited by low temperatures.

Freezing.—Those birds are best for freezing which have been killed by the sticking-debraining method, dry-picked, and dry-cooled. Poultry which has been scalded does not freeze with good results, for the cells already contain absorbed water, which, when subjected to the freezing process, may form sharp ice crystals which disrupt the tissues, disfiguring the appearance of the bird. Quick freezing is desirable for retention of an attractive appearance of the bird. Undrawn poultry is frozen at a temperature of 0°F. or below, and may be stored at a temperature not above 15°F. As a rule, freezing of any kind of poultry is carried out at subzero temperatures. In some instances the surface of the birds is covered with a thin film of oil to reduce the amount of evaporation which is otherwise likely in freezing and storage at such low temperatures. Poultry is also frozen in packages, using the Birdseye belt, or multiplate system.

In this case the product is wrapped in moistureproof transparent wrapping material inside a cardboard container, thereby lowering the incidence of desiccation and freezer burn.

Some idea of the chemical composition of the edible portions of poultry may be gained from the analyses by Atwater and Bryant (Table 80). The viscera, head, lower legs, feathers, etc., are obviously not included. It is apparent that proteins generally furnish the main source of nutritive value. The proportions of the various constituents are observed to vary considerably in chickens and the mature adult fowls, the latter showing a higher fat content and a lower percentage of water. In turkeys the trend is even greater in the same respect, *i.e.*, higher fat content and less water. The percentages are also likely to vary considerably with breed, sex, age, and the feeding of the birds.

TABLE 80.—CHEMICAL COMPOSITION OF POULTRY (EDIBLE PORTION)

Content	Average composition, per cent		
	Chickens and broilers	Fowls	Turkeys
Water	74.8	63.7	55.5
Protein (N × 6.25)	21.5	19.3	21.1
Fat	2.5	16.3	22.9
Ash	1.1	1.0	1.0

The Federal Inspection of Live and Dressed Poultry.[1]—In 1926 an inspection service was established by the government for the investigation and certification of the "class, quality, and condition" of farm products, including poultry, in behalf of shippers or other parties interested in such inspection. Fees for such poultry inspection in New York, the largest poultry market, are collected from the parties concerned with having the inspection performed, mainly members of the Poultry Commission Merchants Association.

The inspection of both live and dressed poultry is conducted by the Bureau of Agricultural Economics. The necessity for such inspection and supervision is evident in the rejection of large quantities of poultry unfit for human food, and the benefits due to such inspections include the confidence of the public in government-inspected products, and the elevation of the poultry industry to a higher level.

The inspection of live poultry is concerned principally with the health of the birds. It also prevents deception and fraud by setting limits to the weight of crops, and the examination of the feed for the presence of prohibited materials.

[1] IVES, L. D., Federal Inspection of Live and Dressed Poultry, *New Jersey Pub. Health News*, **18**, 160–167, 1934.

Unhealthy birds may be detected in the shipping cars by the fact that they have been crowded into the corners by the healthier birds. Certain respiratory infections of poultry may be detected by characteristic odors which are easily recognized by a trained inspector. Birds which by their appearance are judged to be diseased or emaciated and to be unfit for human food are removed from their cages and destroyed. Cars in which diseased birds are found must be cleaned and disinfected under the direction of inspectors of the Bureau of Animal Industry. In cars in which the condition of disease is generalized, the most common causes of the rejection of birds have been roup and infectious laryngotracheitis; in cars in which disease is not generalized, the causes of rejection have been "emaciation, roup, dropsy, bruises, fractures, toxemia, and birds in moribund conditions." Birds may be rejected for fowl cholera, tuberculosis, limberneck, or emaciation.

Poultry is divided into broilers and fowls and other larger birds in respect to the examination of the crops. Broilers weighing less than 2.5 lb. must have a crop weight of 1 oz. or less; fowl and the larger classes of birds must not carry crops weighing more than 2 oz. (2 oz. or less). The weight of the crop is estimated by manual examination.

The presence of such prohibited substances as sand and gravel in the feed, which sometimes are used to increase weight of the birds, may cause the rejection of a load of poultry.

Dressed poultry is inspected by properly trained veterinarians only. Since most poultry is received at canning plants in the frozen state, it is necessary to thaw the material in tanks of water before proceeding with the inspection. After this preliminary preparation, the birds are singed, placed on trays on a conveyor, an incision made in the skin between the legs and abdomen, and the "legs broken down." A circular opening (incision) is made in the abdomen, the breast pushed up and the internal organs exposed. If a bird is found unfit for human consumption, it is placed in a can and subsequently destroyed.

According to Ives, of 1 million birds rejected for human consumption the causes of rejection were as follows:

64 per cent tubercular
15 per cent decomposed
7 per cent septicemic
3.5 per cent emaciated
10.5 per cent "abscesses, tumors, peritonitis, leucemia, concretions, etc."

Ninety-nine per cent of the tubercular birds have shown lesions in the spleen, a lower percentage lesions in the liver. Lesions are seldom found in the lungs.

EGGS

The production of eggs and that of poultry are so closely related that it would be impossible to separate them. Each may be considered in a sense the by-product of the other. The two make up a source of food material which evidently is becoming of greater importance each year. Apparent egg consumption in the period 1927–1931, 20.3 dozen per capita per year, was higher than in any similar period for which statistics are available and indicates that 243 eggs or their equivalent in egg products were utilized per person annually.

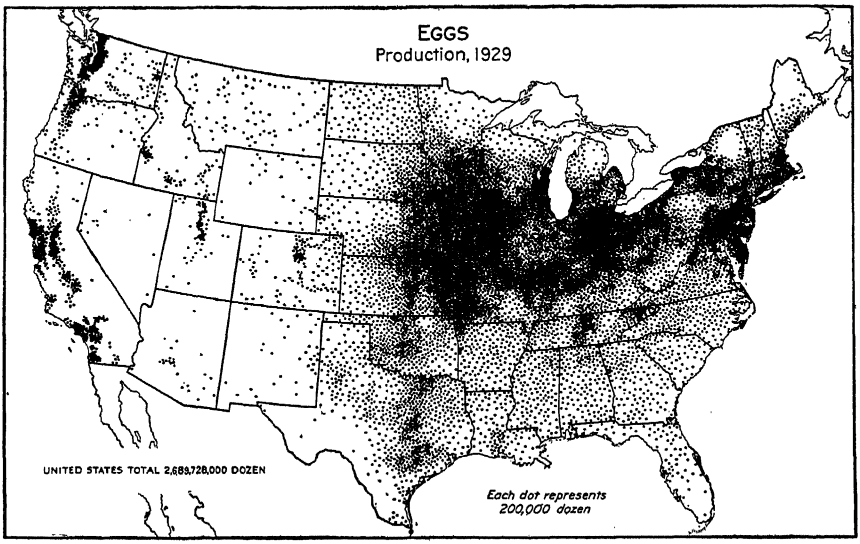


Fig. 32.—(*U. S. Dept. Agr.*)

With the great variety of uses of eggs as a food or a component of foods it would be difficult to supply a satisfactory substitute. Probably no greater concern is expressed by the consumer regarding the quality of any food than is that expressed regarding the "freshness" of eggs. In spite of the fact that the production of eggs is a minor source of income to many persons who maintain poultry flocks, the fact that eggs must be kept as nearly fresh as possible has caused a much more widespread interest in their handling and proper care than is probably the case with any other food except milk. Certain districts have made egg production a primary industry rather than a side line, and in this case the eggs are produced and transported with dispatch only equaled in the dairy industry. A notable example of this sort is Sonoma County in California, where there exists an intensive egg industry.

The largest producing states are Iowa, Missouri, and Illinois, where vast food supplies are available for poultry food because of the grain, particularly corn, grown there.

Small flocks may produce a considerable number of eggs with only a minimum of attention, provided there is loose feed at hand, and many farms have a surplus of eggs which are sold or "traded in" for other foodstuffs not grown on the farm. With many farms in the rural areas, a great surplus is created, which flows toward the consuming areas, the large centers of population, principally in the Middle Atlantic and New England states. Some stop en route, and at certain seasons of the year, when production greatly exceeds consumption, millions of eggs go into cold storage where they are kept under most carefully regulated conditions until the demand has caught up with the decreasing production.

There has been a marked improvement in the methods of handling eggs in the past 20 years, particularly because of better understanding regarding the relation of low temperatures to egg quality and the great improvements in refrigeration. The use of low temperatures to maintain quality should start at the farm, be continued in transportation, and end only when the eggs are used by the consumer. The "physiological age" of an egg, from the standpoint of biochemical and physical changes which have taken place since it was deposited in the nest, is the proper index of quality rather than "chronological age," or the length of time elapsed since laying. This is because an egg if kept under proper condition with refrigeration may be fresher than much "younger" eggs which have been carelessly allowed to remain at warm temperatures, even though for shorter periods of time.

An egg is in reality one of the most interesting structures one can study among the many foods we have on the modern table. It has the chemical and biological elements necessary for the development of a new individual, together with an abundant food supply for the newly developed chick until it emerges from the shell. The exterior covering of an egg, so comparatively simple in structure as it appears to the naked eye, would hardly seem to be the container for such a complex organism as is contained therein. To many city consumers the color of the shell is considered an index of quality, although this idea is based on false premises. Peculiar as it may seem, brown-shelled eggs in Boston command slightly higher prices than white ones and the reverse is true in certain other districts, notably New York, even though this color has nothing to do with freshness or nutritive value. There is one factor concerning the exterior of an egg shell which is a real index of quality but less widely known, *viz.*, the "bloom." A recently laid egg has a characteristic dull appearance owing to an extremely thin layer of protein material deposited on the shell just before the egg leaves the hen. This bloom is removed

mechanically by handling, particularly under conditions of dampness, and its loss gives rise to a gloss which is indicative of an egg no longer fresh in the strictest sense. The extremely thin layer of gelatinous material serves a useful function for the egg as it tends to restrict the entrance of microorganisms, molds, and bacteria, which are otherwise capable of gaining access through microscopic pores or holes in the shell and may spoil the egg.

The shell itself which is about $\frac{1}{60}$ in. thick, if viewed under the microscope, is found to be far from a solid impermeable wall. Although composed largely of calcium carbonate interlaced with fibers, it is permeable in places where the holes or pores exist, and if the protective outside layer is removed and the egg is wet, microorganisms find little difficulty in growing through. These same pores may enable moisture to leave the egg if the outer coating is gone and if the exterior air is warm and dry. When fertile eggs are incubated, these pores are the means by which air passes through the shell to furnish oxygen to the developing embryonic chick.

Fitting snugly against the interior of the shell is one of the two membranes which make up the so-called membrana testacea. The outer one, known as the shell membrane is thicker, stronger, and thus better able to stand a strain than the inner or egg membrane.

When the egg is newly laid and warm, the two membranes, which are fibrous and composed of chitin, are in contact with each other at all points because the volume of the shell is completely filled. On cooling from its initial temperature when laid to atmospheric temperature there is a slight reduction in volume of the egg contents, and a small air space may be noted in the larger end of the egg because the egg membrane recedes from the shell. Thus an air space is left between the two membranes, which may increase in size if the volume of the egg contents decreases any further. Evaporation or loss of water would tend to cause such a decrease in volume and results in a larger air space and for this reason the size of the air cell of an egg may be used as an index of quality and, to some extent, of age.

Between the egg membrane and the yolk is the so-called white of the egg which is gelatinous in character and comprised of albumins. The peripheral or outer portions of the white are comparatively thin and watery in character. Within this layer of white is the middle thick white which in turn surrounds another layer of inner thin albumin. Immediately surrounding the yolk is another layer of thick albumin. In eggs of poor quality the thick white may become thin and watery, but in a fresh egg it should be jell-like and sufficiently firm to retain its form when placed on a wire mesh having only three or four strands to the inch.

Within the white is a spherical yellow or golden yolk, bounded by a delicate membrane known as the vitelline membrane, from the opposite ends of which extend tiny twisted cords which act in a sense as an axis for the yolk. These cords, the chalazae, enable the yolk to turn or twist so that the germinal disk which is the vital cell of the whole egg, located at the surface of the vitelline membrane, may be always on the upper side or top of the yolk so that if the egg is fertilized, those conditions which favor proper development of the embryo are obtained. Warmth is necessary and this position insures the essential heat from the body of of the hen. The yolk, which varies in color from a pale yellow to deep orange depending on the diet of the hen, is made up of what appear on close examination to be alternate layers of dark yolk separated by narrow

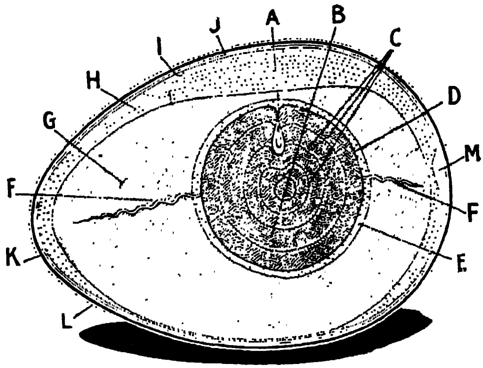


FIG. 33.—*A*—germ; *B*—yolk; *C*—layers of fat; *D*, *I*, *J*—membranes; *E*, *H*—thin albumin; *F*, *F*—yolk anchors, or chalazae; *G*—thick albumin; *K*—shell; *L*—bloom; *M*—air cell. The exact constitution of the layers of thick and thin white is a matter of current scientific investigation—authorities now tending to agree that there are four, including an intermediate layer or pocket of thin white in the area shown as thick white in the diagram. (*Courtesy the Institute of American Poultry Industries, Chicago.*)

bands or concentric rings of light yolk, which combine with the yolk stalk that connects the germinal disk with the center of the yolk.

In contrast to the white which is composed of albumin and water, the yolk is rich in fat and protein with lower concentrations of water. These constituents are in an emulsion which is fairly stable in character. Egg yolks contain vitamins A, B, C, D, and G, and are considered excellent sources of the fat-soluble vitamins A and D. The whites are relatively poor sources of all the vitamins, except possibly vitamin G. The green feeds of the hen are doubtless intimately related to the fat-soluble vitamins in eggs as well as to the color of the yolk. When such feeds are absent from the diet, the color of the yolk is reduced to a marked extent.

Table 81 gives the approximate composition of whole eggs, yolks, and whites.

TABLE 81.—PERCENTAGE COMPOSITION OF EGGS

	Refuse, mainly shell	Water	Protein	Fat	Ash
Whole egg	11.2	65.5	11.9	9.3	0.9
Whole egg (edible portion)		73.7	13.4	10.5	1.0
Egg white		86.2	12.3	0.2	0.6
Egg yolk		49.5	15.7	33.3	1.1

Each egg originates from a minute germ cell or ovum produced in the ovary of the hen which is located in the median line of the hen's body directly beneath the backbone. Many cells of this sort are present in the ovary of a laying hen at the same time but vary in their maturity. Each is surrounded by a membrane and during its early stages rests in a follicle or sac where the cell increases in size owing to the deposition of layers of fat and protein which eventually make up the yolk. The germinal disk or ovum moves toward the outer surface of the yolk as the yolk develops, leaving in its wake the light-colored or white yolk stalk. A period of about two weeks is necessary for the egg to develop to this extent from its earlier diminutive size.

After the yolk has attained full size, it leaves the ovary and starts its passage through the oviduct. This must be preceded, however, by a rupture of the follicle which had served as a protection for the yolk until this time. The opening to the oviduct is close to the ovary and has a funnel-shaped opening which facilitates the entrance of the ovum which has broken away from the follicle. The oviduct has a ciliated lining and contractile tissue which serve to assist the yolk in its passage. During this slow movement the secretory cells of the oviduct produce a dense albuminous layer which accumulates on the yolk and also gives rise to the chalazae. As the developing egg progresses along the oviduct other layers of albumin, less dense, are deposited on the surface. Later the shell membranes are produced as the egg continues its journey. The egg next reaches the uterus, where special glands secrete around the egg membrane a lime solution which soon becomes the shell. In this same organ a last deposit of albumin is added which completely fills the egg, now bounded by a shell. Lastly the egg with its shell passes through the vagina, where the characteristic coloring of the shell and the thin protein film which gives the egg its fresh appearance and protects the interior against invasion are deposited.

If fertilization of the egg takes place, it occurs in the oviduct when the ovum comes in contact with sperm cells which are motile. The sperm cells are male sex cells produced in the testes of the male birds which are

transferred to the cloaca of the hen during the mating process. From the cloaca the sperms continue up the oviduct until contact is established with the descending ovum. Usually only one sperm is able to enter a single ovum because immediately after the entrance there is believed to be a protective mechanism set up by the ovum which prohibits the entrance of others.

The division of the ovum proceeds immediately following fertilization, and even during the short period of a day or two before the egg is laid, the embryonic organs of the chick are in process of formation. The entire period required for development of the chick is 21 days, but the most rapid development from an embryological standpoint occurs during the first few days.

It frequently happens that eggs which are destined for food purposes become fertilized, and the above developmental changes are undesirable under such conditions. The longer eggs are allowed to remain in the nest or elsewhere at high temperatures, the more complete such development will be. Since such changes may be detected by certain means of examination, fertilized eggs are generally rejected on inspection.

For the same reasons eggs which are known to be unfertilized, as would be the case if hens in a flock are segregated from the males, sometimes command slightly higher prices.

It is somewhat difficult for any one not thoroughly familiar with eggs to tell a good egg from a bad one unless the shell is opened. Those with obvious stains, dirt, cracks in the shell,, etc., are looked on with suspicion and are generally priced lower, because of their poor appearance and the likelihood of lower internal quality. Some other means of judgment is necessary, however, for the appraisal of the quality of that vast majority of eggs which enter the egg markets of the world while still in the unbroken shell. The most common and only satisfactory means other than breaking out the egg contents is the use of light or "candling." The term is not an accurate one at present as the use of candles is now obsolete and electric lights are used exclusively.

Candling, which is usually done in a dark room, is accomplished by holding an egg by hand in front of a small lighted orifice so that a relatively strong light beam about the diameter of a half-dollar will enable a fairly distinct comparison of color, density of contents, size of air cell, and mobility of the contents when observed by the person holding the egg. The egg is held so that the air cell is uppermost and is turned slowly so that the movement of the yolk may be noted.

This examination is made to ascertain a number of facts. By it one may determine the size of the air cell, which increases in size in eggs when they become older or if they are not properly kept (which generally means not refrigerated). Candling also enables one to observe the movement

of the egg contents, particularly the yolk, and this movement is restricted in high-quality eggs by the firmness of the white. The poorer the egg, the more movement allowed the yolk and the nearer it may approach the shell when twirled. The dimly visible yolk is an evidence of quality as it indicates a thick firm white which prevents a distinct outline. Candling also may give evidence of the development of an embryo within the egg. Meat spots and blood clots, which may be present because of lesions in the oviduct of the hen during the formation of the egg may likewise be detected and such eggs are set aside for other uses, although they are in no sense dangerous as food. The presence of bacterial rot and mold growth may also be determined by the light of the "candle," and such eggs are rejected.

Candling is capable not only of separating edible and inedible eggs, but it also is helpful in establishing egg grades and in differentiating between relatively young eggs kept under optimum conditions and those of lower quality.

The following grades of eggs have been established in Massachusetts and numerous other states, following standards set up by the U. S. Department of Agriculture.

United States Standards of Quality for Individual Eggs

Quality factors	U. S. Special	U. S. Extra	U. S. Standard	U. S. Trade
Shell....	Clean: sound	Clean: sound	Clean: sound	Clean: sound
Air cell..	1/8 in. or less, localized, regular	2/8 in. or less, localized, regular	3/8 in. or less, localized, may be slightly tremulous	May be over 3/8 in., may be bubbly or freely mobile
Yolk....	May be dimly visible	May be visible	May be visible: mobile	May be plainly visible, dark in color, freely mobile
White...	Firm, clear	Firm, clear	Reasonably firm	May be weak and watery
Germ....	No visible development	No visible development	Development may be slightly visible	Development may be clearly visible, but no blood showing

As given in *Egg Standardization Leaflet* 2, issued by the U. S. Dept. Agr., revised May, 1929.

In order to keep eggs in the higher quality grades, attention has been focused on devices for keeping eggs at low temperatures while in transit, and by means of carefully maintained refrigerator cars eggs may now travel from the Pacific coast to the great markets on the Atlantic and arrive in a condition not markedly different from that in which they left

the nest. Trucks, steamboats and store cabinets maintained at refrigerator temperatures supplement the refrigerated warehouse egg rooms which are strictly maintained at definite humidity as well as temperatures, in order to keep eggs in a condition of high quality over periods of time. The standard unit for shipping eggs is a case holding 30 dozen, with separators between the individual eggs. The cases have standard dimensions such that a standard egg car will hold 400 cases.

Cold Storage of Eggs.—Eggs may be stored successfully for periods of 9 months or longer if kept at a temperature slightly above their freezing point. It is essential, however, that egg rooms have proper relative humidity, adequate ventilation, and freedom from odors. The relative humidity considered optimum is between 75 and 85 per cent, depending on temperature. Lower humidities cause greater losses in moisture from the eggs, which is undesirable, while, on the other hand, higher humidities are likely to favor the development of molds on the shells. Thus the setting of humidity conditions is a compromise between these opposing factors. A temperature between 31 and 32°F. is quite common for egg storage, although slightly lower temperatures are possible with spring eggs which have less watery albumin. Ventilation is aided by raising the egg cases a few inches above the floor of the egg room by use of strips of wood and by placing narrow strips between cases. Under best conditions, no other foods or commodities are stored in the same room in order to prevent the absorption of odors from other materials by the eggs. A few cold-storage warehouses have installed in their ventilating systems an apparatus for producing ozone which is said to be useful in cutting down the odors and reducing somewhat the incidence of microorganisms in the air, when the ozone is used in concentrations of only a few parts per million.

Eggs are rarely kept in cold storage over a year, and, generally, are removed in large part for sale during the winter months before the next year's production of new eggs has again lowered prices.

Under the best storage conditions there are biochemical changes which go on in eggs with the passing of time. These changes include a slow breakdown in the proteins with the production of ammonia in amounts detectable by chemical methods. The acidity of the fats is likely to increase and likewise a progressive development of mustiness, off flavors, and odor is apparent as the storage time lengthens. All of these factors tend to emphasize the importance of eggs being in the finest possible condition when the storage period starts. Low-grade eggs have already begun to deteriorate when put in storage, and changes in them are apt to be accelerated under such circumstances.

In Denmark a method of treating eggs has been used whereby they are subjected to a vacuum to exhaust the air from the air cells and then

subjected to an atmosphere of carbon dioxide and nitrogen and stored at refrigerated temperatures.[1]

Some idea of the value of eggs and their production in various sections of the United States may be gained by Table 82.

TABLE 82.—EGG PRODUCTION AND VALUE, 1933

Region	Millions of eggs	Value per dozen, cts.
North Atlantic	4,146	20.5
North Central.	15,726	11.5
South Atlantic.	2,668	15.7
South Central.	5,256	11.2
Western.......	4,017	16.2
Total.......	31,813	13.6

This table, based on U. S. Department of Agriculture statistics, evidences the large percentage of eggs produced in the North Central states, where the prices are relatively low compared with those obtained in the seaboard states where large population and lower production increase the value of eggs.

A method of egg processing used to favor the keeping qualities of eggs is to dip them in a bath of mineral oil heated to a high temperature for a very short exposure time, usually only a matter of seconds. This action tends to kill such microorganisms as are on the shell and at the same time leaves a relatively impermeable coating which retards moisture losses due to evaporation and the escape of carbon dioxide.

Sandblasting.—Under the conditions which eggs undergo in being laid, especially when the nests are not clean, a certain percentage are likely to have dirt spots on the shell. Such eggs command distinctly lower prices because of their poor appearance and therefore a method of increasing the value has been devised whereby they may be treated by a sandblast. The membranous covering is largely removed by such treatment. The eggs are placed on rubber-surfaced rollers which cause a rotation of the eggs as they are conveyed into a small chamber where the rotation exposes all the surface of the egg to a sandblast brought about by compressed air. An exhaust fan recovers the sand which may be cleaned and used again. This method is most efficient in removing hard, dry material from the exterior of the shells. Apparatus of this nature has been constructed capable of cleaning thousands of dozens of eggs a day.

Washed Eggs and Their Detection.—Egg producers frequently wash spots and detritus from eggs when no other means of removal are avail-

[1] *Ice and Cold Storage*, **38**, 85, 1935.

able. This improves the appearance but may impair their keeping quality, especially if they are to be stored for some time. In view of the latter fact, a means of detecting washed eggs is sometimes helpful.

Clean, unwashed eggs contain both potassium and chlorine (chlorides) on the exterior of the shell. Washed eggs do not have these elements unless washed in solutions containing them. Qualitative tests for these elements have been used, cobalt nitrate being employed for potassium, and silver nitrate for the chlorides.

An extract may be made by placing a drop of distilled water on the shell of the egg which drop is later transferred to a microscope slide, where the reagent is added. A positive test for chloride is indicated by a flocculent precipitate when a drop of 0.1 *N* silver nitrate is added. With the addition of a drop of cobalt nitrate to the shell extract, crystals form within 20 minutes if potassium is present. The results of the test are best observed microscopically with 20- to 40-fold magnification.[1]

Detection of Scraped Eggs.—Scraped or abrased eggs may be detected by the use of dye solutions such as methylene blue, brilliant green, malachite green, and safranine. These dyes stain protein materials and as the egg is normally covered with a thin film of protein, the presence of unstained spots will indicate that this exterior film of protein has been removed.

Eggs are sandblasted to remove dirt spots or in some instances to remove evidence that the eggs are previously oil-dipped. Such eggs can be detected by microscopic examination of the shell.

Oil-treated eggs may be determined by dipping the end of an egg in ether and noting the appearance of an oily ring at the edge of the evaporating surface. This test is reliable even on oil-treated eggs which have been sandblasted.

Frozen Eggs.—Eggs are used in large quantities by bakers, mayonnaise makers, candy manufacturers, and in other food industries. In many instances supplies of eggs are needed over the whole year by such users, even though eggs are less plentiful in the winter months and usually higher in price. As during the late spring and early summer months the production of eggs is very great, in fact much larger than the demand, these surplus eggs were formerly stored and later taken from the refrigerated storage and used by such manufacturers.

This handling of thousands of egg cases and their contents has given way to a considerable extent to a more efficient method, *viz.*, that of "breaking" the eggs in sanitary cooled establishments close to the source of supply, placing them in large metal containers, and freezing the eggs immediately. Such plants are generally as carefully controlled and clean as a model kitchen, the operators dressed in clean white uniforms

[1] For details of these tests, see P. F. Sharp, *J. Ind. Eng. Chem.*, **24**, 941–946, 1932.

each day, and the containers sterilized with care equal to that given our milk bottles in the modern dairy establishment. Under this system it is possible to use eggs of edible quality which are checked, irregular in size, thin-shelled, or slightly lower in quality than the best market eggs, but nevertheless whose contents are firm and good for any purpose. Often the whites and yolks are separated because they are or may be used for different purposes. Great care is taken in selecting the eggs and rejecting those which are questionable because it is well known that one poor egg, with a bad odor, is likely to spoil a whole can of eggs containing many dozens.

All such egg-breaking establishments usually candle all incoming eggs before they go to the women who do the actual breaking. The eggs should be chilled before breaking, although they are generally under refrigeration even previous to their arrival at the plant. Cooling facilitates the separation into whites and yolks. The eggs are broken by trained operators, usually women, by striking the egg on a blunt knife edge. If the eggs are to be separated into whites and yolks the egg contents are dropped into a small metal separating device which holds the yolk and cuts off the white. The meats, or the separated white and yolk, are put in small glass or metal cups and each smelled by the operator to detect mustiness. If abnormal odors are detected such eggs are immediately discarded. The control methods used by the operators are a close approach to surgical sterility because the breaking apparatus must be sterilized if a single poor egg has contaminated it.

Egg yolks and unseparated whole eggs are usually thoroughly mixed or churned until they become a homogeneous mass before pouring them into the cans in which they are frozen. Such care has resulted in products which have proved dependable, and consequently the demand for such frozen eggs has increased tremendously in recent years among food manufacturers.

It may not be an untimely prediction to suggest that some of us will see the day when the housewife will buy frozen eggs for most culinary use just as we have seen the increasing use in the home of other frozen foods which save the handling and transportation of refuse which must ultimately be discarded.

Frozen eggs are kept at very low temperatures until needed for use, and in addition to being maintained in their original good quality have decided economic advantages. They are obtained at low prices because egg prices are lower during those months of high production. They avoid shipment of useless shells and require less storage space. The fact that they may be stored in tight cans eliminates the shrinkage due to evaporation which is bound to go on if they are stored for any extended period in the shell, even under refrigeration. Spoilage is eliminated

which might otherwise be progressive as the unfit eggs are rejected at the source of production before expensive shipment charges are incurred.

The temperature used in freezing the eggs is usually 0°F. or below, and storage temperatures are of about the same order.

Certain types of trade eggs for baking and hotel trade are mixed with sugar and then frozen. As sugar would ultimately be incorporated in the products made from these eggs and as it acts as an aid in preserving certain physical characteristics desired in the eggs, this process is often advantageous.

In some of the larger cities there has developed a demand for "chilled" eggs, or eggs, yolks, or whites which have been taken from the shell but not actually frozen. Such "chilled" eggs usually amount to a very small percentage when compared with the frozen-egg trade, and obviously they must be used immediately. This modification requires that the egg-breaking establishment be not far from the user, otherwise the products should be hard frozen.

In this country a standard case of 30 dozen eggs weighs about 42 lb. net and if all of the eggs are usable, yields about 35 lb. of egg meats.

Dried Eggs.—Another egg product which has gained wide usage in the food industries is dried eggs, either in the form of dried unseparated eggs, dried yolks, or albumin (whites). An annual consumption of from 5 to 10 million pounds has taken place in the United States in recent years, and although much of the product is imported from China, the business is largely carried on by American or European companies which maintain establishments of a modern character and are capable of supplying high-grade products.

The method of breaking eggs for drying is similar to that used for frozen eggs. The egg yolks are dried in some plants by a spray process whereby the liquefied yolk is sprayed under high pressure into a heated chamber maintained at 160°F. or higher. The fine powder which results is packed in airtight metal-lined cases for export.

The use of belts or drums made of aluminum, passing through heated chambers is another means of drying yolks, whereby thin films are dried on the metal and then scraped off in flakes. The same methods may be used for unseparated eggs.

The whites are placed in vats and allowed to undergo a fermentation process, with the resulting acidity later neutralized by the addition of adequate amounts of ammonia. After clarification and settling, the whites are dried in pans or on belts in a room or tunnel at a temperature of about 120°F. Care must be exercised to keep the heat within definite limits because the coagulation point of egg albumin is only a few degrees higher than the drying temperature. Albumin is used in making meringue. marshmallow, and similar products where its whipping quali-

ties are of paramount importance, so the powdering of the flakes is highly undesirable.

Dried yolks and unseparated eggs have a considerable use in prepared cake and doughnut flours. The yolks are used to a slight extent in the ice-cream industry.

The keeping qualities of all dried-egg products depend on their being kept in a dry condition, otherwise spoilage is bound to ensue. It is also desirable to keep them as cool as possible, and to protect them from the air because of oxidative changes which are unfavorable.

CHAPTER XI

MILK

A better understanding and keener appreciation of the value of milk and milk products have increased the importance of milk in the American dietary. In 1930 it was estimated that there were some 30 million dairy cattle in the United States, with an annual production of over 100 billion pounds of milk, which signifies that there was one dairy animal to approximately every five persons.

In addition to the increased knowledge regarding the value of milk and its products as food, there have been marked advances in the methods used for the production and handling of these commodities in the tremendous quantities which are required to supply the demand.

The following standards and definitions for milk and milk products were established by the Secretary of Agriculture of the United States in 1933.

Milks

1. Milk is the whole, fresh lacteal secretion obtained by the complete milking of one or more healthy cows, excluding that obtained within 15 days before and 5 days after calving, or such longer period as may be necessary to render the milk practically colostrum-free. The name "milk" unqualified means cow's milk.

2. Pasteurized milk is milk, every particle of which has been subjected to a temperature not lower than 142°F. for not less than 30 minutes and then promptly cooled to 50°F. or lower.

3. Homogenized milk is milk that has been mechanically treated in such a manner as to alter its physical properties, with particular reference to the condition and appearance of the fat globules.

4. Evaporated milk is the product resulting from the evaporation of a considerable portion of the water from milk, or from milk with adjustment, if necessary, of the ratio of fat to nonfat solids by the addition or by the abstraction of cream. It contains not less than 7.8 per cent of milk fat, nor less than 25.5 per cent of total milk solids; provided, however, that the sum of the percentages of milk fat and total milk solids be not less than 33.7.

5. Sweetened condensed milk is the product resulting from the evaporation of a considerable portion of the water from milk to which sugar and/or dextrose has been added. It contains not less than 28 per cent of total milk solids, and not less than 8 per cent of milk fat.

6. Dried milk is the product resulting from the removal of water from milk, and contains not less than 26 per cent of milk fat and not more than 5 per cent of moisture.

7. Malted milk is the product made by combining whole milk with the liquid separated from a mash of ground barley malt and wheat flour, with or without the addition of sodium chloride, sodium bicarbonate, and potassium bicarbonate, in such a manner as to secure the full enzymic action of the malt extract, and by removing water. The resulting product contains not less than 7.5 per cent of butter fat and not more than 3.5 per cent of moisture.

8. Goat's milk and ewe's milk are the whole, fresh lacteal secretions free from colostrum obtained by the complete milking of the healthy animals, and conform in name to the species of animal from which they are obtained.

Skim Milks

9. Skim milk, skimmed milk, is that portion of milk which remains after removal of the cream in whole or in part.

10. Evaporated skimmed milk is the product resulting from the evaporation of a considerable portion of the water from skimmed milk, and contains not less than 20 per cent of milk solids.

11. Sweetened condensed skimmed milk is the product resulting from the evaporation of a considerable portion of the water from skimmed milk to which sugar and/or dextrose has been added. It contains not less than 24 per cent of milk solids.

12. Dried skimmed milk is the product resulting from the removal of water from skimmed milk, and contains not more than 5 per cent of moisture.

13. Buttermilk is the product that remains when fat is removed from milk or cream, sweet or sour, in the process of churning. It contains not less than 8.5 per cent of milk solids not fat.

14. Cultured buttermilk is the product obtained by souring pasteurized skimmed or partially skimmed milk by means of a suitable culture of lactic bacteria. It contains not less than 8.5 per cent of milk solids not fat.

The composition of fluid milk, which doubtless deserves the appellation "the most nearly perfect food,"[1] varies considerably according to the animal from which it is obtained. In the United States milk is almost exclusively from cows, although in certain other countries goats, sheep, horses, and other animals are more commonly used as sources of milk.

The differences in average composition of milk from various animals is shown in Table 83 taken from Fundamentals of Dairy Science.[2]

Although the components cited in Table 83 are representative of the average composition of cow's milk, it must be emphasized that there is considerable variation in the composition of milk from different breeds of cows, the Jersey and Guernsey breeds being particularly noted for their high fat content, which may run well over 5 per cent. Other difference in the chemical composition of milk may be noted between individual cows of

[1] See Crumbine and Tobey, The Most Nearly Perfect Food. Williams and Wilkins, 1929.

[2] Associates of Rogers, Fundamentals of Dairy Science. Chem. Cat. Co.

any particular breed and even in the milk of the same cow during the various phases of its milk-production period.

TABLE 83.—AVERAGE COMPOSITION OF MILK FROM VARIOUS ANIMALS
(Per cent)

Content	Cow	Goat	Sheep	Horse
Water	87.27	84.14	81.90	90.68
Casein	2.95	3.04	4.57	1.27
Albumin	0.52	0.99	1.26	0.75
Fat	3.66	6.00	6.52	1.17
Lactose	4.91	5.02	4.82	5.77
Ash	0.69	0.81	0.93	0.36

The secretion of milk is intimately associated with the general physiology of the producing animal. The mammary glands, in which milk is produced, are composed of branching tubes or ducts lined with secretory cells. These ducts branch and form tiny cellular end-buds called alveoli. On the outside of the secretory cells are innumerable capillaries. Substances from the blood of the animal diffuse out of the capillaries into the gland cells and are there chemically changed into the fluid we call milk, which is a fluid particularly suitable for the nourishment of the offspring. The milk thus formed in the cells bordering the alveoli passes from the interior of the cells into the central cavity or lumen of the alveoli and thence through the mammary ducts to the gland cistern. The milk cistern connects with the teat cistern from which the milk may be suckled by the young animal, removed by human hands or by use of milking machines.[1]

There is a tendency for the composition of milk from a given cow to remain rather uniform in spite of variations in the diet, which may be partially accounted for by the regulation of the glucose, amino acids, and phosphatides within the blood of the animal. However, the composition of the milk, especially the milk fat, may be altered somewhat by diet. Deficiency in the food intake of the animal results in a lower yield of milk because the food materials essential for milk production are also those necessary for other body functions. Continued deficiency in food intake, however, reduces the animal's supply of reserve materials such as glycogen and adipose tissue or even muscle tissue which may be indirectly converted into milk in emergencies. Milk production is also seriously affected by excessive exercise, cold, heat, and mastitis. Those breeds which produce milk of high fat content are generally not the largest milk producers. Cows of Holstein breed are notably high-milk-volume producers, but the fat content of their milk is likely to be lower.

[1] TURNER, C. W., *Missouri Agr. Exp. Sta. Bull.* 339, 1934.

Standards.—Such marked differences in composition and quality of milk are possible that health authorities have set up standards for milk, and even grades of milk, to insure consumers getting the quality and type of milk they are paying for. These standards are concerned not only with chemical quality, but equally with purity from the standpoint of bacteriological quality, a factor which is generally indicative of the safety of a milk supply. When used intelligently, such standards protect the public and encourage the production of not only pure but also safe milk, with all its health-giving and nutritive qualities unimpaired.

The following regulations and standards for milk were established by the Milk Regulation Board of the Commonwealth of Massachusetts in 1935.[1]

The following official grades of milk are hereby established.

(*a*) Milk—Raw.
(*b*) Milk—Pasteurized.
(*c*) Grade A Milk—Raw.
(*d*) Grade A Milk.
(*e*) Special Milk—Raw.
(*f*) Special Milk—Pasteurized.
(*g*) Certified Milk—Raw.
(*h*) Certified Milk—Pasteurized.

(*a*) MILK—RAW, shall be produced on a dairy farm that complies with all pertinent rules, regulations and minimum requirements legally made or promulgated by the Milk Regulation Board, the Department of Agriculture, the Department of Public Health, or local board of health, in effect at the time of such production, and no portion of such milk shall be drawn from the cow more than seventy-two hours prior to the delivery of such milk to the consumer. Milk—Raw shall show a bacterial count of not more than four hundred thousand colonies per cubic centimeter. When Milk—Raw is sold, or offered, or exposed for sale, each container thereof shall bear a label or be covered with a cap bearing the words MILK—RAW.

(*b*) MILK—PASTEURIZED shall be Milk—Raw, pasteurized, in compliance with section 1 of chapter 94 of the General Laws, (Ter. Ed.) in establishments operated in accordance with the regulations made by the Department of Public Health under authority of section 48A of said chapter 94, and such milk shall show a bacterial count of not more than four hundred thousand colonies per cubic centimeter before pasteurization and of not more than forty thousand colonies per cubic centimeter when delivered to the consumer. When Milk—Pasteurized is sold, or offered, or exposed for sale, each container thereof shall bear a label or be covered with a cap bearing the words MILK—PASTEURIZED, and, if in bottles, such caps shall have been affixed only by means of a machine capper.

[1] Rules and Regulations Establishing Grades of Milk, Regulating and Establishing Standards in accordance with the provisions of the General Law (Tercentenary Edition). Chap. 94, Sec. 13, as amended by Chap. 263 of the Acts of 1933.

(*c*) GRADE A MILK—RAW shall be only milk produced on a dairy farm which has in possession, or is entitled to receive, in addition to a certificate of registration issued by the Director, if so required by law, a printed, written, or stamped statement, in full force and effect, signed personally or in facsimile form by the Director, based upon inspections of such dairy farm made by the Milk Regulation Board, the Department of Agriculture, the Department of Public Health, or local board of health at least twice a year at intervals of not less than five nor more than seven months, and to be physically attached to such a certificate, if any, stating that such dairy farm has upon inspection been found to conform, in addition to the requirements for the production, processing, labeling, and sale of Milk—Raw issued by the Milk Regulation Board or by the local board of health, to the following requirements for the production, processing, labeling, and sale of Grade A Milk—Raw.

All cows on such dairy farm shall have been tested within twelve calendar months prior to the original inspection, and thereafter at intervals of not exceeding twelve months, by the tuberculin test under state and federal supervision and found not to react thereto, or shall be part of an accredited tuberculosis-free herd under state and federal supervision, or shall be part of a herd located in a modified accredited area under state and federal supervision.

The hair on or near the udder and flanks of every such cow shall be kept properly clipped. Such cows shall be milked only into hooded metal milk pails or with clean milking machines.

GRADE A MILK—RAW shall be delivered to the consumer within forty-eight hours after the earliest time of drawing from the cow. Any portion thereof shall show a bacterial count of not more than one hundred thousand colonies per cubic centimeter when delivered to the consumer, shall be milk containing not less than four per cent of milk fat and not less than twelve and two-tenths per cent of total milk solids, and at retail, shall be sold, or offered or exposed for sale only in bottles covered with a cap that will protect from contamination the pouring lip of the bottle. Every such cap coming in contact with such milk shall be affixed only by means of a machine capper. Every exposed cap shall bear the words GRADE A MILK—RAW and the day of the week on which such milk was produced. No such milk shall be bottled later than twenty hours after the earliest time of drawing from the cow any portion thereof.

(*d*) GRADE A MILK shall be only GRADE A MILK—RAW which has been pasteurized within the commonwealth, in compliance with section 1 of chapter 94 of the General Laws (Ter. Ed.), in establishments operated in accordance with the regulations made by the Department of Public Health under authority of section 48A of said chapter 94 of the General Laws (Ter. Ed.), and in accordance with said section, provided that immediately prior to such pasteurization all apparatus used therefor or therein shall have been thoroughly cleaned and sterilized. No such milk shall be pasteurized later than forty-eight hours after the earliest time of drawing from the cow any portion thereof, and when delivered to the consumer such milk shall show a bacterial count of not more than ten thousand colonies per cubic centimeter. Grade A Milk, when bottled, shall be bottled immediately after pasteurization and only at the place where such milk is pasteurized. The bottles shall be capped immediately after filling in the manner

prescribed for capping Grade A Milk—Raw, except that the exposed cap shall bear the designation GRADE A MILK, the word PASTEURIZED, and also state the day of the week on which such milk was pasteurized.

(*e*) SPECIAL MILK—RAW shall be only milk produced on a dairy farm which has in possession, or is entitled to receive, in addition to a certificate of registration issued by the Director if so required by law, a printed, written, or stamped statement, in full force and effect, signed personally or in facsimile form by the Director, based upon inspections of such dairy farm made by the Milk Regulation Board, the Department of Agriculture, the Department of Public Health, or local board of health, at least twice a year at intervals of not less than five nor more than seven months, and to be physically attached to such certificate, if any, stating that such dairy farm has upon inspection been found to conform, in addition to the requirements for the production, processing, and labeling, and sale of Grade A Milk—Raw issued by the Milk Regulation Board or by the local board of health to the following requirements for production, processing, and labeling, and sale of Special Milk—Raw.

Before any person is engaged as a milker or is employed in handling Special Milk—Raw, he must obtain from the Massachusetts Department of Public Health a certificate stating that on the evidence obtained by the examination of specimens submitted as coming from him he is not a typhoid carrier. No person shall be so engaged or employed at any time who has a sore throat or is suffering from tuberculosis, diarrhea, or dysentery or who is a typhoid carrier.

Special Milk—Raw shall conform to the Massachusetts legal standard for milk, shall be delivered to the consumer within 48 hours after the earliest time of drawing any portion thereof from the cow, and shall show a bacterial count of not more than fifty thousand colonies per cubic centimeter when delivered to the consumer, shall be bottled only at the place where produced, and at retail, shall be sold, or offered, or exposed for sale only in bottles. Each bottle containing such milk shall be capped with a cap which will protect from contamination the pouring lip of such bottle and every such cap coming in contact with such milk shall be affixed only by means of a machine capper. Every such cap shall bear the designation SPECIAL MILK—RAW and the day of the week on which such milk was produced. No such milk shall be bottled later than twenty hours after the earliest time of drawing from the cow any portion thereof.

(*f*) SPECIAL MILK—PASTEURIZED shall be only Special Milk—Raw which has been pasteurized within the commonwealth in compliance with section 1 of chapter 94 of the General Laws (Ter. Ed.) in establishments operated in accordance with the regulations made by the Department of Public Health under authority of section 48A of chapter 94 of the General Laws (Ter. Ed.) and in accordance with said section, provided, that immediately prior to such pasteurization all apparatus used therefor or therein shall have been thoroughly cleaned and sterilized. Such milk, when delivered to the consumer, shall show a bacterial count of not more than five thousand colonies per cubic centimeter. Special Milk—Pasteurized, when bottled, shall be bottled immediately after pasteurization and only at the place where such milk is pasteurized. The bottles shall be capped immediately after filling in the manner prescribed for capping Special Milk—Raw, except that the caps shall bear the designation SPECIAL MILK—

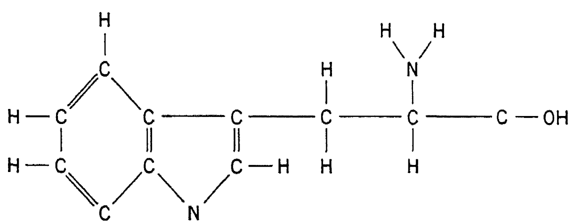
PASTEURIZED, the day of the week on which such milk was pasteurized, and may also bear a statement of the minimum percentage of butter fat contained in such milk.

(*g*) CERTIFIED MILK—RAW shall be only milk produced in accordance with sections 20 to 25, inclusive, of chapter 180 of the General Laws and amendments thereto (Ter. Ed.) and the rules and regulations of the Department of Public Health made thereunder and with the standards of purity and quality for certified milk established by the American Association of Medical Milk Commissions in effect when such milk is produced.

(*h*) CERTIFIED MILK—PASTEURIZED shall be only Certified Milk—Raw, pasteurized, in compliance with section 1 of chapter 94 of the General Laws (Ter. Ed.) at the place where such milk is produced, only in establishments operated in accordance with the regulations made by the Department of Public Health under authority of section 48A of chapter 94 of the General Laws (Ter. Ed.) provided that immediately prior to such pasteurization all apparatus used therefor or therein shall have been thoroughly cleaned and sterilized. No such milk shall be pasteurized later than twenty hours after the earliest time of drawing from the cow any portion thereof. Such milk, prior to such pasteurization, shall contain not less than four per cent milk fat as provided by the regulations of the American Association of Medical Milk Commissions in effect when such milk is produced and, subsequent to pasteurization and when delivered to the consumer, shall not show a bacterial count of more than five hundred colonies per cubic centimeter. Such milk shall be capped in accordance with the standards established by the American Association of Medical Milk Commissions and every such cap shall bear the words CERTIFIED MILK—PASTEURIZED and the day of the week upon which such milk was pasteurized.

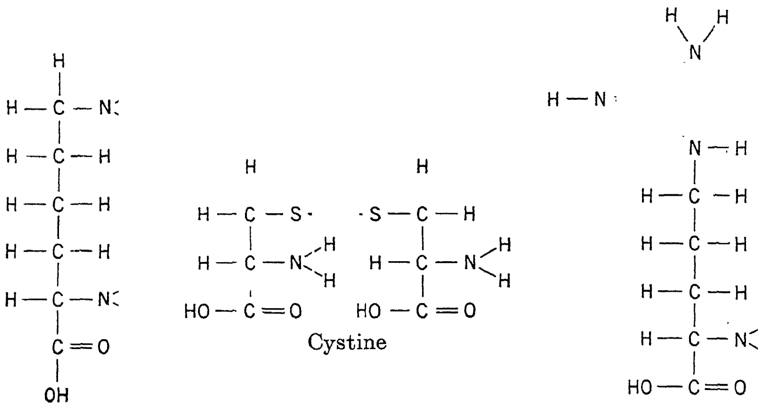
Nutritive Value.—The nutritive value of milk is based largely on the fact that this food is a natural one for the development of the young of any species of mammals. Cow's milk contains the chemical compounds necessary for the growth and wellbeing of man and has them in such proportions that with slight modification they may be used as food for infants. It contains carbohydrates, fats, proteins, minerals, and vitamins, all of which are essential for human metabolism and growth.

Proteins are utilized in the human body for the building of new tissue and the maintenance and repair of body cells. Not all proteins are adequate to supply the needs of the body, but casein, the principal protein



Tryptophan

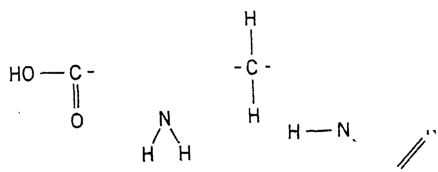
found in milk, is classed as a complete protein, for it contains the amino acids most necessary to replace the proteins which are essential to the human body. These amino acids include tryptophan, lysine, histidine,



Lysine

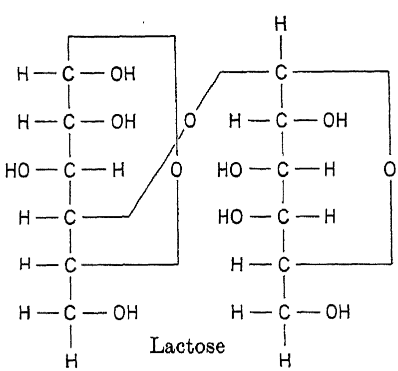
Cystine

Arginine



Histidine

and cystine which are essential, as well as arginine and perhaps others of importance. For this reason milk is often cited as the best source of food protein.



Lactose

Carbohydrates, which are contained in milk as lactose or milk sugar, serve as valuable sources of energy and heat for the human body. The fats which are also sources of fuel in body metabolism are likewise found present in milk.

Calcium and phosphorus, elements which are essential to the development of teeth and the bony structures of the body, are constituents of milk. In fact, milk is considered one of the best sources of utilizable calcium. A slight deficiency in iron, which may easily be furnished by small amounts of other foods in the diet, alone prevents milk from being called the perfect food instead of the "most nearly perfect food."

Recent years have brought forth even further proof that milk has valuable properties in the dietary of man. With the development of the newer knowledge of nutrition it has been amply demonstrated that milk is one of the best sources of vitamins, those food accessories so necessary to health, which even in small quantities prevent certain so-called deficiency diseases. Milk is an excellent source of vitamin A, which prevents ophthalmia and is essential to growth, general health, resistance to disease, and fertility. Vitamin B, the antineuritic vitamin which prevents beriberi, is also found in milk in sufficient amount to consider milk a good source. Vitamin C, the antiscorbutic vitamin, is found in milk but in variable amounts, the quantity being generally lower during the winter months. The mineral metabolism of the body, especially that of calcium and phosphorus, is intimately connected with the presence of vitamin D, which is called the antirachitic vitamin. Vitamin D is also found in milk, but the quantity of this vitamin is dependent to a great extent on the diet and environment of the cow which produces the milk. This fact has caused the commercial development of several methods whereby the vitamin D content of milk may be increased, by irradiating with ultraviolet light, either the cow, the food of the cow, or the milk after it has been taken from the cow. There is another vitamin, E, which is present in milk, and is concerned with the prevention of sterility, although there is little evidence that a deficiency of this vitamin occurs in the diets of human beings. Since the vitamins were first named or lettered, it has been found that vitamin B is a composite of two or more separate factors, and vitamin G is now applied to B_2 or the antipellagric vitamin, which was formerly believed part of the characteristics of vitamin B. Milk is considered an excellent source of this vitamin.

The heat treatment necessary for the pasteurization of milk has been found to lower the quantity of vitamins A and C which are present in milk, but milk is not expected to act as the sole source of these vitamins in the diet. Even infants are fed auxiliary foods which supplement deficiencies of this nature which may occur.

Utilization of Milk.—From the above facts it is apparent that milk has many qualities which make it an ideal food, for both the young and the old. Probably the bulkiness of milk is the main factor which prevents adults from making fluid milk an even larger constituent of their diet. The quantity of milk which is consumed indirectly in the form of cream, butter, cheese, ice cream, bakery and pastry products, and other materials, adds to the volume of milk consumed, although this is not always realized by those who sometimes think of themselves as consuming very little milk. Concentrated milk in various forms has also become a factor of large proportions in recent years, especially in the form of evaporated,

condensed, and powdered milk. Table 84 gives some indication of the usage of milk in various forms.

TABLE 84.—APPARENT YEARLY PER CAPITA CONSUMPTION IN THE UNITED STATES, 1931

Milk equivalent	96.6 gal.	Evaporated milk	13.70 lb.
Milk (cities and villages)	40.0 gal.	Condensed milk	2.29 lb.
Butter	18.00 lb.	Ice cream	2.42 gal.
Cheese	4.49 lb.	Oleomargarine	1.72 lb.

In addition to milk used by human beings and that made into various dairy products, it is also used in considerable quantities for the feeding of calves and other farm animals. Skim milk is also utilized for this purpose after the cream has been removed and may also be used as a source of lactose and casein for food or industrial purposes.

TABLE 85.—SUPPLY AND DISAPPEARANCE OF MILK IN THE UNITED STATES, 1930–1933*
(Millions of pounds)

Item	1930	1931	1932	1933
Supply	106,563	108,299	106,992	107,185
Farm production	99,736	101,970	101 863	102,309
Nonfarm production	2,826	826	826	2,826
Imports of fresh milk and cream	158	12	12	3
Imports of manufactured dairy products	739	662	580	508
Stocks on hand Jan. 1	3,104	2 829	711	1,539
Disappearance	106,563	108 299	106,992	107,185
Exports of fresh milk and cream	2	1		
Exports of manufactured dairy products	281	224	160	119
Fed to calves on farms	2,976	2,964	2,806	2,800
Stocks on hand Dec. 31	2,648	1,711	1,539	3,885
Human consumption†	100,656	103,399	102,487	100,381

* Estimates of the U. S. Bureau of Agricultural Economics.
† On the basis of these figures the per capita consumption of all dairy products, in terms of milk equivalent, was 817 lb. in 1930, 833 lb. in 1931, 821 lb. in 1932, and 799 lb. in 1933.

Breeds of Dairy Cattle.—Only about 3 per cent of all the dairy cattle in the United States, or about a million animals, are pure-bred. The other 97 per cent are of mixed breeds. The pure breeds are Ayrshire, Brown Swiss, Dutch Belted, Guernsey, Holstein-Friesian, and Jersey. Each of these breeds is the result of the work of breeders over many generations in an effort to improve the milking capacity of their herds, and to be a pure-bred animal certain requirements set up by associations for that breed must be met. An animal having one or both parents not of pure breed is called a grade. Besides the dairy breeds mentioned, there are some dual-purpose animals which are beef animals as well as milk

producers. These dual-purpose breeds include the Shorthorn, Red Polled, and Devon breeds.

Records of pure-bred animals and their parentage are kept by name and number in the herdbook of the various associations so their line may be established. Additional production records are also maintained concerning milk production and the proving of bulls having tested daughters.

The Holstein-Friesian pure-breds are by far the most numerous, with Jerseys second, and Guernseys third. Holstein cattle are raised in all our states but particularly in New York, Wisconsin, Pennsylvania, Ohio, Michigan, and Illinois. They produce larger quantities of milk and lower average butter fat than any other breed. This breed was first imported into the United States in about 1795 from Northern Holland and Northern Germany. Their color is black and white.[1]

The Jersey breed came from the Isle of Jersey, between England and France, and were first imported here in 1850. These animals are also widely distributed in the United States. Their color may be fawn or cream, gray, brown, or almost black, sometimes spotted with white. The size of this breed is smaller than the others. The average butter-fat percentage was 5.35 for some 37,000 cows and heifers up to 1929, in contrast with an average of 3.38 for Holsteins.

The Guernsey breed also came from the Channel Islands near France and when first brought to America in 1830, the animals were called Alderneys. Guernsey cattle are commonly fawn and white in color, although they may approach a light cherry color. The legs are usually white, even if the remainder of the body is all colored. This breed gives a high fat content milk, averaging about 5 per cent in the official records.

The Ayrshires and Brown Swiss breeds are less numerous in this country. The former are more common in Northeastern States, the latter in New York and the Midwest.

Pure-breeding is a wise undertaking for the dairy man as it means better production, but to build up such a herd takes both time and money. Much more interest seems apparent in this direction at present than has been the case in the past.

Bacteriological Aspects of Milk Production.[2]—Freshly drawn milk is not free from bacteria. The number present may vary from a few hundred to thousands per cubic centimeter of milk. If the foremilk (the first few streams from each quarter) is rejected, the bacterial count is usually reduced, because the foremilk is notably high in bacteria. High bacterial counts on fresh milk may indicate an infected udder, but sometimes apparently normal animals may produce milk with bacterial counts of

[1] NYSTROM, Dairy Cattle Breeds, *U. S. Dept. Agr. Farmers' Bull.* 1443, 1930.

[2] See HAMMER, B. W., Dairy Bacteriology, 1928, for a thorough discussion of this subject.

many thousand bacteria per cubic centimeter. Bacteria occur normally in milk as a result of contamination of the ducts and the milk cistern of the udder.

After milk is drawn from the udder, there are numerous possibilities of contamination from other sources. These sources include bacteria from the exterior of the cow, also from the milker, manure, the air of the stable, the milking utensils, the milk can, the cooling water used, and other environmental sources. Flies may also be either direct or indirect sources of contamination. It is essential in the production of milk that all sources of contamination be reduced to the lowest possible levels.

Those sources of contamination likely to introduce types of bacteria which are causative of human diseases must be eliminated as far as possible. The cow is capable of infecting the milk with the bacteria causing bovine tuberculosis, *M. tuberculosis.* These organisms may be transmitted directly to the milk by infected animals, or through the agency of either feces or saliva. Particles of feces from tuberculous cows present an obvious vehicle of possible infection if such material gains entrance to the milk. Such dangers may be obviated by the elimination of tuberculous cows from dairy herds as has been brought about extensively by the use of the tuberculin test for cattle. Some states now make the proud claim that all dairy cows within their borders have been found free from this disease. It seems reasonable to hope that the time will come when every state may be able to do likewise, as remarkable progress has been made in this direction since 1917, even though the cost involved has been tremendous. The process of pasteurization, which will be discussed later, has played a large part in lowering the incidence of bovine tubercle infection in man, but should be considered as no more than a substitute for the far more preferable method of wiping out the disease in dairy cattle.

Another disease transmitted to man from diseased cows through milk is undulant fever, which is attributed to cows suffering from *Brucella abortus* infection. As the agglutination test is reliable for the detection of *Brucella abortus* infection, also called Bang's (abortion) disease in cattle, it is possible to test cows for the presence of this disease and remove them from dairy herds. Precautions must, of course, be taken to prevent adding to the herd any cattle which are not found free of this disease thereafter.

In addition to the diseases of cows to which man is subject, there are other diseases transmissible through milk. Typhoid fever is recognized as one of this type which involves the human element. In this instance it is the human carrier of typhoid fever who must be eliminated, whether he be the milker, or the milk handler in some later stages of the rather involved processes through which milk is sometimes required to undergo before it reaches the final consumer. Suitable tests for the detection of

human typhoid carriers are well known and should be used to eliminate such persons from participating in milk-handling operations. As persons who have recovered from typhoid fever may be intermittent carriers for long periods, it is desirable to prohibit their employment as milk handlers.

Septic sore throat and scarlet fever may be transmitted through milk both directly, through the infection of milk by a milker or dairyman, or indirectly by infection of a cow's udder by human carriers. The possibilities of direct infection are believed of less importance, because it would seem that the numbers of infective organisms would be much larger if the

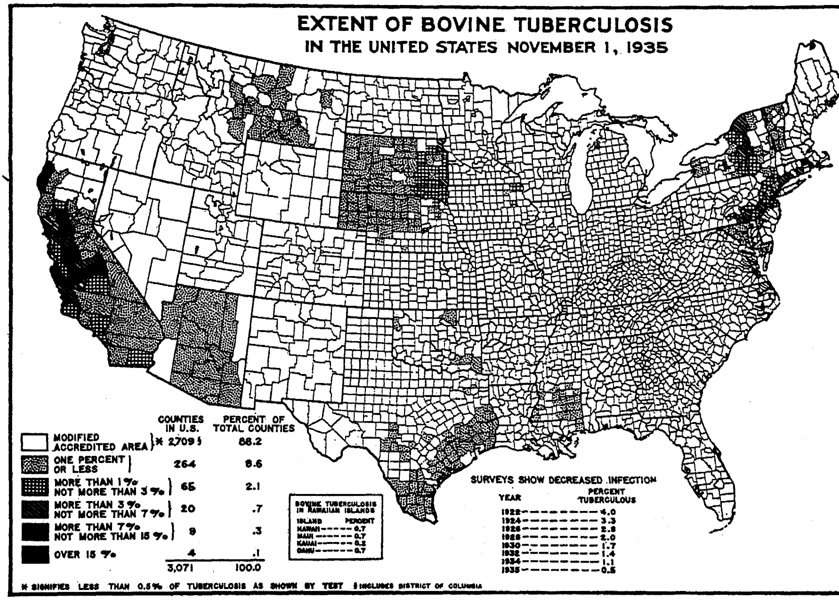


FIG. 34.—(*Courtesy U. S. Dept. Agr., Bureau of Animal Industry.*)

infection developed in the secondary host, the udder, from which they might be discharged in tremendous numbers if the infection were not noted. *S. epidemicus* and *S. scarlatinae* have both been found in the udders of cows which had been infected by milkers, and milk from such cows has caused milk-borne epidemics of the respective diseases.

The dangers of hemolytic streptococci, which are not infrequently found in milk, both from cows exhibiting udder inflammation and those which do not, would seem to depend largely upon whether the species present were of human origin, or of bovine origin and incapable of causing infections in man.[1]

[1] See HARDENBERGH, J. G., Technical Supervision in the Production of Highest Quality Milk, *Am. J. Pub. Health*, **20**, 705, 1930.

One of the possible causes of streptococci in large numbers in milk supplies is mastitis, an udder infection sometimes called "garget." It is a more common cause of trouble in cattle than is sometimes realized, as it may occur in subacute or chronic forms.[1] Frequent veterinary inspection is helpful in diagnosing the presence of the disease in the cows. The use of bromthymol-blue indicator is useful in testing the milk for evidences of mastitis. The indicator will turn a greenish-blue color with the foremilk if the test is positive for mastitis except just after calving, or just before the period of lactation ends.

The use of the strip cup or strainer may also serve as a means of detecting mastitis. Small particles or flakes of coagulated milk on the wire mesh are usually obtained if the animal has a severe mastitis infection.

Many factors have been cited for this type of infection which causes great economic losses owing to lowered milk production and lower quality milk. The disease is of bacterial origin and may be instigated by injuries to the udders or teats. It is doubtless aggravated in many ways and latent mastitis may exist in animals for years with severe outbreaks only at unpredictable intervals. Although the common bovine mastitis may not be the cause of human disease, it is a serious problem to the dairy industry as the disease is highly infectious among cattle.

Much study has been given to attempts to lower the incidence of this disease in dairy herds, but it is difficult to eradicate permanently. Animals showing evidence of this condition should be removed from the herd. In addition to careful attention to dairy hygiene, it has been found helpful to milk the animals last which have a past history of mastitis, even though they are apparently well at the time. It has also been suggested that the animals in their first lactation period be grouped together and milked first, the second lactation group next and so on in order to prevent early infection of the younger animals.[2]

To control this disease segregation of infected animals must be practiced rigidly, and care should be taken to see that any replacements to the herd are not suffering from the same type of infection. Strict sanitary supervision over the segregated animals should be maintained and the milk should not be used for human beings. If used for young stock, it should be boiled before feeding.

Laboratory examination may be used to check the incidence of streptococci in milk, but as mastitis is often a chronic disease, frequent examinations are necessary.

Numerous other microbes have been reported as causes of disease in man and transmissible through milk. The above are those which are

[1] HUCKER, G. J., and P. A. HANSEN, *J. Bact.*, **27**, 73, 1934.

[2] PLASTRIDGE, ANDERSON, WHITE, and RETTGER, *Storrs Agric. Exp. Sta. Bull.* 197, 1934.

of primary concern to both health officials and those who are concerned with the improvement of the quality of milk supplies.

Freshly drawn milk exhibits a weak antiseptic action on bacteria which is probably more inhibitory or restraining than germicidal. This action varies to a considerable extent in different animals and even in different milkings from the same animal, but there is usually an actual reduction in bacterial numbers soon after milk is drawn.

Bacterial reductions due to this antiseptic property of freshly drawn milk are not of sufficient magnitude to be of any practical significance in the dairy industry. Heating the milk has been shown to inactivate this property. The only dependable method of reducing bacterial counts in milk already drawn is by the use of pasteurization or heat treatment.

Milk Storage and Temperature Relations.—The bacteria which are present in milk when it is drawn, or those which enter it thereafter, develop at a rate dependent on the temperature at which the milk is held and according to the types of organisms which are present. A good milk held at 32°F. will keep satisfactorily for days, 10 days being given as the usual limit of safe storage. At 40°F. it is possible to store milk safely, but the storage time is less than at 32°F. Variable results may be obtained by storage at 50°F., dependent upon the types of bacteria present. Acid or abnormal fermentations may result. Storage between 60 and 65°F. favors the development of the bacteria causative of ropy milk. If stored at 70°F., the conditions are ideal for the growth of *S. lactis*, which causes souring. Gas production by members of the Escherichia-Aerobacter group is likely to accompany or follow the *S. lactis* fermentation. Yeasts capable of fermenting lactose develop rapidly at this temperature. Undesirable flavors and odors are likely to be rapidly produced. At higher temperatures even more rapid chemical and biological changes occur.

These considerations make it imperative that milk be cooled immediately after drawing from the cow to a temperature below 50°F. Such procedure not only retards chemical changes in the milk but retards the growth of any disease microorganisms which may have found their way into the product. Milk should be kept cool until it is consumed, with a single exception, which is at the time of the pasteurization process. Immediately after this procedure is completed the milk should again be cooled.[1]

Sanitation in the Dairy.—Many improvements have been made in dairy barns to better conditions under which cows are fed and milked, with the particular object in view of producing a safer and higher quality milk. Many barns now exhibit better sanitary conditions than some

[1] See Bowen, Refrigeration in the Handling, Processing and Storing of Milk and Milk Products, *U. S. Dept. Agr. Misc. Pub.* 138, 1932.

human homes. The clean appearance of a barn is not, however, an infallible index of the quality of milk produced therein, as the human element in the milking operations is of great importance. Carelessness on the part of the dairyman may cause trouble regardless of the fine appearance of the plant and its equipment. Conversely it is possible to produce milk of high quality in barns of poor construction, with almost scanty equipment, provided the man in the barn understands and practices rigidly those principles which are essential to the exclusion of bacteria, and follows the methods needed to keep bacteria from multiplying rapidly.

There are many factors which are of concern in producing safe milk of high sanitary quality. Both the cows and the persons coming in contact with the animals and the milk should be healthy and free from communicable disease. The equipment such as pails, milking machines, strainers, cans, and coolers must be not only thoroughly clean but should be sterilized if possible.[1] To accomplish this, adequate supplies of pure water and means to heat it are necessary. Sterilizing equipment using steam or hot air is essential for most effective results. Provision should also be made for the proper storage of milk containers and equipment after washing, in order to prevent access of flies and vermin.

The personal habits of the milker and his methods of cleaning the cows, which should always be completed previous to the milking operations, are of considerable influence on the bacterial content of the milk. His care in noticing abnormal conditions in the cows and eliminating such animals from production is also of importance, although veterinary supervision in this respect is desirable. The maintenance of conditions with a minimum of dust in the barn is helpful in keeping the bacterial content low, *although the cleanliness of pails and cans* is likely to play a more important role in this respect.

The Handling of Milk.—The immediate removal of milk to a rigidly clean, screened milk room where the milk may be cooled within a short time is required in many producing areas. This milk room should preferably be entirely separate from the cattle barn, but if it is too distant, there is a great temptation for the milker to neglect using it in stormy or winter weather.[2]

In the milk room the milk is usually strained through cloth, gauze, or absorbent-cotton filters which remove much of the visible dirt present in the milk if such material has gained access during the milking operations. This process causes no definite decrease in bacterial counts but is carried out because visible dirt in milk is an evidence of carelessness in

[1] Dahlberg and Marquardt, *N. Y. State Exp. Sta. Bull.* 612, 1932.

[2] For designs of milk rooms see Kelley and Hotis, *U. S. Dept. Agr. Farmers' Bull.* 1214.

production. If the strainers are not cleaned thoroughly, however, or replaced when they show visible dirt, this practice may result in increases in bacterial counts owing to contamination.

Centrifugal milk clarifiers may be used to remove suspended solids or sediment in the milk at the dairy but are more commonly used at milk plants and receiving stations. Such mechanisms are helpful in removing body cells from the milk as well as visible dirt, but do not improve the product otherwise. A recently developed clarifier is said to accomplish clarification without breaking the fat clusters or influencing bacterial counts.

Milk Cooling.—All dairies should be equipped with some facilities for cooling the milk as rapidly as possible. This may be accomplished in part by the use of surface coolers before the milk is put into cans or the filled cans may be subjected to refrigeration. If large containers are used for milk which has not been pre-cooled, it is essential that the product be placed at temperatures sufficiently low and agitated regularly so that all the milk may be reduced from body temperature in a relatively short time.

Milk is often precooled just after milking by running it over the outside of a metal cooler shaped like a truncated cone, and which contains chopped ice or has a stream of cold water running through the interior. Needless to say, this type of cooler requires very careful cleaning after each usage.

There are numerous other methods which are used for cooling milk in cans on the farm, which range from the use of water in or from springs and shallow wells to the most modern mechanical refrigeration. While the former may be unsuited for cooling milk in hot weather because the water sometimes becomes too warm to act as an effective refrigerant, the water from deep wells may generally be employed advantageously. The use of chopped ice and water in the cooling of milk has long been practiced satisfactorily, but care must be taken that sufficient ice is used.

The storage tank is a tank holding cold water and may or may not be insulated. The cans or jugs of milk are set into the water, which may be cooled by ice or mechanical refrigeration. When 10-gal. jugs are used, the time necessary for cooling may be materially shortened by stirring the milk to aid in heat transfer.

The dry-box method of cooling makes use of a mechanical-refrigeration unit which is installed in the upper part of an insulated compartment. Refrigerated brine circulates through the pipes of a tubular surface cooler and reduces the temperature of the milk as it is allowed to flow down over the outside of the pipes. The same brine is used to maintain a low temperature in the storage compartment, in which the milk is placed in containers after cooling.

Control of Milk Supplies.—The maintenance of quality milk production requires consideration of the factors stated and others of a similar nature. Constant and perpetual checking, much of which must be done by milk-control officials, is essential. Such officials may be the representatives of municipalities, states, large producers, or dealers. Their function is a protective one, in the sense that the safety of the consumer is the paramount objective. This is just as true when the milk is to be pasteurized as otherwise, because the fact that pasteurization is to occur subsequently should not lower standards in the slightest degree. The inspector, however, should consider his primary mission as that of a guide and teacher, and assume the role of an enforcement agent only in case the prescribed regulations are deliberately evaded or broken. Much has been done to educate the dairyman in the use of better methods, and improvements in methods are still being made.

The fundamental considerations are to get milk of low bacterial content from healthy cows, and by the use of refrigeration to keep bacterial reproduction and concomitant chemical changes at a minimum, as well as to prevent the access of other bacteria which may be harmful. The use of proper refrigeration checks reproduction at the rapid rates which would otherwise occur. The use of heat in the subsequent pasteurization process lowers bacterial populations to a marked degree, after which milk should be again refrigerated immediately.

The joint responsibility of accomplishing these requirements lies with the farmer, the dealer, and milk-control officials. No one duty concerns any other branch of the food industries to a greater extent or requires any more personnel to accomplish its purpose. No single public-health activity has ever received greater attention or required the same amount of research, according to the National Science Advisory Committee Report of 1935. Nevertheless, a number of epidemics occur each year, owing to milk as a vehicle, although the extension of pasteurization is bound to lower this number as years go by.

The following essential elements of the public-health supervision of milk supplies were advocated by the Committee on Milk Production and Control at the White House Conference on Child Health and Protection in 1931.[1]

a. Inspection of farms and plants.

b. Supervision of the physical examination and testing of cows.

c. Laboratory inspection of milk.

d. Physical examination of workers and residents at farms and plants, including laboratory examination of body discharges.

e. Pasteurization control of market milk.

[1] *Pub. Health Repts.*, **46**, 769–811, 1931, Reprint No. 1466.

A high degree of supervision is maintained by many of the large milk producers within their own organizations, particularly among those who produce certified milk, which must meet the requirements of the American Association of Medical Milk Commissions in various large cities. The extent to which such care in production extends is evident from the outline of technical control reported by Hardenbergh as in operation on a few farms.[1]

The technical control of production now in operation on a few farms comprises four divisions of activity: medical, veterinary and laboratory supervision, and nutritional control. While functioning in a special way, each division is interdependent and cooperative with the others.

Medical supervision embraces physical examinations of all dairy employees before employment with special attention directed to signs of tuberculosis and venereal disease, and special examinations to detect carriers of typhoid and other pathogens.

This primary examination is followed up by weekly reexaminations of all milk handlers and by a system which provides for efficient daily medical attention as required, associated with quarantine and hospital facilities.

Veterinary supervision is organized with three principal purposes: To prevent disease among the milk cows and other cattle in the herd; to detect disease, when it does occur, at the earliest possible moment, and take the necessary measures for isolation and cure or eradication; and to supervise the sanitary requirements in the production and handling of the milk. Veterinary supervision is accomplished:

1. By examination of all cows prior to purchase or by supervising the raising of healthy dairy heifers for replacements.
2. By supervision of the entire herd by trained personnel.
3. By inspection of the milk from each quarter of the udder of every cow in the producing herd prior to each milking. (This inspection constitutes the "foremilk" examination and is one of the most important routine procedures in detecting abnormal milk and early indications of mastitis.)
4. By repeated tuberculin tests and removal of reactors.
5. By repeated blood tests for *Br. abortus* infection and removal of reactors.
6. By a regular and systematic sanitary inspection to insure the maintenance of conditions and the practice of methods which will protect the milk from contamination after it is drawn.

Laboratory supervision has for its principal purposes:

1. To assure that only cows producing normal milk are in the milking line.
2. To assure the cleanliness and practical sterility of all apparatus and utensils in which the milk is handled.
3. To assure the freedom of the milk from pathogenic bacteria.
4. To cooperate with the veterinary forces in the control of animal diseases.

Laboratory controls are in addition to and cooperative with the veterinary supervision, the latter being dependent to an extent upon the laboratory for

[1] Hardenbergh, J. G., *loc. cit.*

information necessary in passing judgment upon the fitness of individual cows for production.

Laboratory supervision is accomplished:

1. By examination of the milk from all new and fresh cows prior to admission to the producing herd. This examination comprises a leucocyte count and a determination of the numbers and kinds of bacteria present. The blood-agar plate method is an indispensable adjunct to the detection of undesirable bacteria that may gain entrance to milk, particularly pathogenic strains of streptococci such as have been shown to be associated with septic sore throat and scarlet fever.

2. By examination of the milk from cows that have been detected by the fore-milker. Flaky milk, for instance, is an early indication of udder trouble. These combined examinations of abnormal milk permit the early recognition of udder ailments, particularly mastitis, and the subsequent early hospitalization and treatment of cases before they become fully established.

3. By examination of the entire producing herd at frequent (weekly) intervals by means of group samples. These tests insure that cows once having been passed for production are under periodic examination to detect any abnormalities that may not be apparent on physical examination of the udder or gross examination of the milk.

4. By so-called equipment and efficiency tests. All apparatus and utensils are checked for cleanliness and practical sterility. These tests serve as checks on all processes of production from the time the milk leaves the cow until it is filled into the final containers.

Nutritional control is essentially quality control in that it is organized to utilize all the scientific knowledge available to aid production of a milk containing every desirable element that can be incorporated by natural means.

Having outlined the control methods for a complete technical supervision of milk production, consideration must be given to the practical application of the plan, its feasibility, and its operability. To suggest that any such plan could be applied to the small farm units now characteristic of the dairy industry or that it could be applied by boards of health, would be to suggest an economic absurdity.

By those who believe in the principles underlying the production of fundamentally sound milk, consideration is being given more and more to the thought of the development of dairy units of sufficient size so that scientific methods of production coupled with complete technical control can be made an economic success. A few such units are already operating. We believe that the principle is sound and that it offers opportunity for the future advancement of clean milk and its relation to health and nutrition.

The Rotolactor.—An outstanding development in the dairy industry in recent years has been the construction of a highly mechanized equipment and system for milking dairy cattle, called the Rotolactor, which uses the most highly developed methods of sanitation and hygiene. The Rotolactor, which was developed by the Walker-Gordon Laboratory Company at Plainsboro, New Jersey, is essentially a huge revolving circular platform designed to facilitate the washing, drying, and milking of cows at the rate of 240 per hour. The huge room housing this equipment is air-conditioned and has tiled walls and floors which are kept spotlessly

clean. The filtering and washing of all air entering the room insure the absence of dust and objectionable odors, and reduce air contamination by bacteria to a minimum.

Cows make their way from the living and feeding barns through a one-way lane which leads to a ramp. They go up the ramp in single file, step onto the platform of the Rotolactor, which is revolving very slowly, and which reminds one somewhat of a merry-go-round platform. The cows are then automatically hitched in stanchions, at the rate of one every 15 seconds. The cow remains in this moving stall for a period of about 12 minutes, during which time the platform makes almost one complete revolution, and in this time the cow is washed, wiped down, and milked.

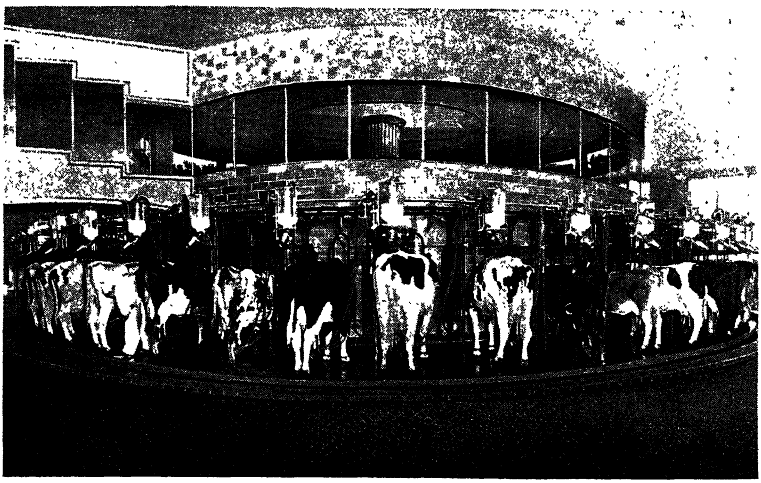


FIG. 35.—The Rotolactor. (*Courtesy Walker-Gordon Laboratory Company.*)

Just before the platform gets around to the starting place, the stanchion is automatically released, the cow walks forward, steps off the platform and goes eagerly down another ramp toward the feeding barn for her waiting dinner.

During the first part of the cycle of the Rotolactor, the udder and posterior quarters of the cow are sprayed with warm water from automatic showers. This is followed by a more careful hosing with warm water under pressure. Each cow is then carefully wiped in the udder section with sterile cloth towels, by hand. Before attaching the rubber-lined cups of the milking machine, the foremilk is withdrawn by hand and examined on a fine-mesh copper strainer. If any abnormalities are apparent the entire milk from that animal is rejected. The milking machine, which is then attached, draws the milk up into an individual pyrex-glass container located above the cow. As the Rotolactor continues its slow but certain journey, the rubber-lined cups are removed from the

teats and suspended above the animal. The cups are automatically washed and immersed in a sterilizing solution so that when the cycle is completed the cups are sterilized and ready for use on the next animal which occupies the same stanchion. At the completion of the cycle, the milk flows automatically from the pyrex jar into a device which weighs and records the quantity. It is then pumped immediately to coolers which reduce the temperature to below 40°F. inside of 5 minutes, and is later bottled and capped.

This process, when used for dairy herds of tuberculin-tested cows which are under the careful control of veterinarians and bacteriologists, is as near ideal as science can expect at the present time. In addition, it has been found that the use of such equipment for the milking of large herds of cows cuts down the expense of milking because it reduces the labor otherwise involved.

Although such an expensive installation would never be possible on small dairy farms, it would seem justified in certain areas where large numbers of milking cows are segregated. This remarkable application of engineering in the practice of milking is encouraging when one considers that some dairymen today have made little improvement in the technique of milking over that used hundreds of years ago.

Milk Transportation.—Milk which is marketed at some distance from the source of production must be cooled and kept at low temperature at several different points before delivery to the customer: at the farm, at the receiving station, during transportation, and at the market-milk plant.

During transportation the general purpose is to maintain existing low temperatures in the milk rather than to lower the temperature, as milk should always be sufficiently cooled before it is transported. Insulated jackets have been commonly used to slip over large cans and jugs to slow down the rate of heat transfer during transportation of milk in this type of container. The milk cars, or baggage cars, in which cans of milk were formerly transported to a considerable extent had galvanized-iron linings, so that chopped ice could be used to assist in keeping the necessary low temperatures during transit, but have many times proved both unsatisfactory and expensive. These cars were largely replaced by insulated cars with ice bunkers at each end, using about 3.5 lb. of ice for each gallon of milk. The use of salt mixed with the ice was found helpful in such installations.

More recent improvements in dairy transportation equipment have developed insulated tank cars and tank trucks for the hauling of milk over considerable distances.[1] These tanks are equipped with pumps or

[1] Hotis, Transporting and Handling Milk in Tanks, *U. S. Dept. Agr. Tech. Bull.* 243, 1931.

compressed air for unloading, agitators, observation windows, lights, and other auxiliary apparatus. No refrigeration is necessary because the large volumes of milk pumped into such containers are thoroughly cooled, generally to temperatures below 40°F. before filling, and the temperature of the milk, even in hot weather rarely increases as much as 2°F. Such tanks should be filled completely to prevent subsequent partial churning of the milk due to agitation produced by the motion of the car or truck. After such tanks are emptied they are thoroughly washed and may then be treated with some disinfecting solution or sterilized with live steam from the milk plant where the cargo is discharged.

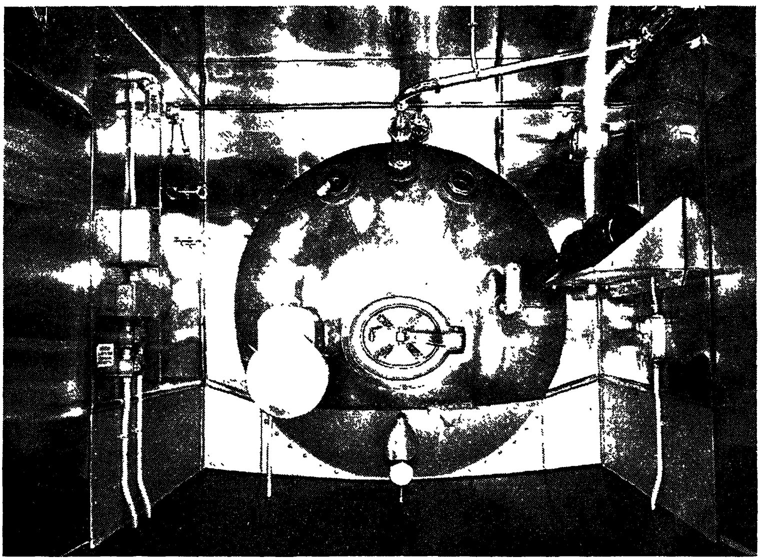


FIG. 36.—Modern milk transport. The interior of a milk-tank car showing the end of one of the two huge tanks used for transporting cooled milk by rail. (*Courtesy General American-Pfaudler Corporation.*)

For short hauls, adequately insulated trucks sometimes refrigerated with cracked ice and salt, solid carbon dioxide ice, or cartridges are employed. The cartridges are generally filled with a liquid having a lower freezing point than water, then frozen, and when solid placed in special compartments in the truck. Insulated tank trucks have come into very general use in certain parts of the milk shed of metropolitan New York and other cities, but present obvious disadvantages in the winter in those regions where there are heavy snow fall and poor road conditions.

The receiving station receives milk from the farms located in its vicinity. At this point, the milk brought in by the farmer is tested, sampled, and immediately cooled, although the latter should have been

already accomplished. Many milk-receiving stations will not accept milk unless its temperature is below 50°F. In some stations in the warm valleys of California the milk is collected by the station trucks, which make calls at each dairy or ranch twice a day to insure the quality of their milk. Storage tanks and adequate refrigeration facilities are generally available in milk stations so that shipments from these points to the large consuming areas may be properly handled.

Refrigeration is equally necessary in the market-milk plant which may receive its supply partly from the receiving stations and partly from nearby farms. Here it may be necessary to store some of the raw milk for a few hours before it is pasteurized, cooled, bottled, and stored ready for delivery. Insulated or refrigerated storage tanks are helpful for keeping some milk on hand in case of delay in delivery and for starting operations on the next day.

By means of tubular regenerators or heat exchangers it is possible to use this cool milk for taking heat from the pasteurized product at a subsequent stage in the processes and thereby conserve additional refrigeration which would be otherwise required. The regenerators also enable savings in heat which is conserved at the same time.

A recent development in dairy refrigeration has been the use of cold water at about 35°F. in place of brine or direct expansion ammonia in the milk cooling tubes. The use of brine has sometimes presented the difficulty of causing milk to freeze on the tubes of the cooling device, a trouble which is eliminated with cold water as a refrigerant.

The actual freezing of milk is not desirable, because as milk freezes there is a separation of ice from its water solution of sugar and salts, the protein and fat which are in suspension acting merely as deterrents upon the rate at which physical equilibria are established. Further heat removal causes continued formation of ice crystals and increases the concentration of the liquid phase. As this concentration is increased, the various constituents of the liquid phase eventually reach their individual saturation points and the separation of these substances probably takes place. The main effect of freezing milk is to destroy its normal physical structure, especially the fat phase, in which a separation of free fat results, thereby causing a loss in cream volume.

The freezing point of milk is of nearly constant value (−0.558 to −0.514°C.) and the determination of this value may be used as an index of whether milk contains added water.

PASTEURIZATION

The application of scientific principles in the dairy industry is very closely interrelated with temperature. In milk, as in most food products, quality is of paramount importance to the consumer. Quality, from the

consumer's standpoint, is largely concerned with flavor, although to the intelligent milk producer and others concerned with the welfare of the consumer, there are other factors not so evident but equally important, namely, freshness, cleanliness, purity, safety, and nutritional value. These factors may be combined in the term healthfulness, and dairy technology is largely concerned with retaining and enhancing these characteristics of healthfulness.

The use of elevated temperatures in certain stages of milk handling is likewise of great importance. Such methods are dependent on the earlier work of the great French scientist, Louis Pasteur, who found as early as 1860 that a few minutes' heating of wine at a temperature of from 120 to 140°F. was sufficient to destroy certain forms of bacteria and yeasts. The term pasteurization now applies especially to processes of heating milk or milk products for definite periods of time and at specified temperatures (140 to 185°F.), depending on the particular process being employed. Milk is pasteurized commercially either by the holding method or by quick treatment at more elevated temperatures, sometimes called the flash process.

The purpose of pasteurization is primarily to kill all disease-producing bacteria that may infect milk supplies. The time and temperature limits set by authorities are those which are believed to offer a suitable margin of safety in killing tubercle bacilli which are the most heat-resistant pathogens likely to be found in milk supplies.[1]

As there have been differences of opinion[2] concerning the thermal death point of tubercle bacilli, various standards have been promulgated and adopted for pasteurization regulations.

Efforts have been made to bring about uniform standards in milk-control practice in the United States and eliminate differences in opinion which at times may be embarrassing to producers or dealers and possibly lower the protection of the consumer.

The U. S. Public Health Service Milk Ordinance and Code which was set up as a guide for this purpose gave the following definition for pasteurization in 1935:

Pasteurization. The terms "pasteurization," "pasteurized," and similar terms shall be taken to refer to the process of heating every particle of milk or milk products to a temperature of not less than 142°F. and holding at such temperature for not less than 30 minutes in approved pasteurization apparatus, provided that approval shall be limited to apparatus which requires a combined holder and indicating thermometer-temperature tolerance of not more than 1½°F., as shown by official tests with suitable testing equipment, and provided

[1] Rosenau, *U. S. Pub. Health Service, Lab. Bull.* 42, 1908.

[2] North and Park, *Am. J. Hyg.*, **7**, 147, 1927.

that such apparatus shall be properly operated and that the indicating thermometers and the recording thermometer charts both indicate a temperature of not less than 143½°F., continuously throughout the holding period. The terms "pasteurization," "pasteurized," and similar terms shall also include the process of heating every particle of milk or milk products to 160°F. and holding at that temperature or above for not less than 15 seconds in apparatus of approved design and properly operated. Provided that nothing contained in this definition shall be construed as disbarring any other process which has been demonstrated as of at least equal efficiency and is approved by the State health authority.

The Effect of Pasteurization on Bacteria.—During the earlier days of commercial pasteurization it was believed that vegetative bacterial cells were largely destroyed during the process, but that putrefactive spore formers survived and these types of bacteria were capable of producing toxins or other harmful products. This was the origin of the idea which persisted for some time that pasteurized milk did not sour, but rotted instead.

Investigations conducted in this country have proved that such is not the case. The examination of properly pasteurized milk has shown it to contain essentially the same proportions of the various types of bacteria, namely, alkali formers, inert organisms, lactic acid producers, and peptonizing types, as are to be found in raw milk. The alkali-forming organisms were generally most numerous, the lactic-acid group next in numbers, and the peptonizers less numerous.

Lactic acid organisms have a relatively high thermal death point and are likely to survive pasteurization because of this thermal tolerance. They are likely to be the preponderant types in poorly pasteurized milk and by the production of lactic acid tend to restrain the growth of the peptonizing types. An "old" taste sometimes develops in pasteurized milk, owing to the activities of the inert or alkali-forming bacteria, but this same taste may occur in milk which has not been heat-treated.

Pasteurized milk held at 50°F. has been shown to maintain a relatively even percentage of lactic acid bacteria over a long period of time while the peptonizing types were restrained.

Pathogenic streptococci are completely destroyed in milk when the pasteurization process is carried out properly. Certain of the more heat-resistant types of streptococci may be found in pasteurized milk, but such survivors are usually of the groups which are not ordinarily associated with disease.

The presence of thermophilic bacteria in pasteurized milk, *i.e.*, types which may grow satisfactorily at temperatures approaching those of pasteurization, may be due to infection of the milk from farm utensils and cans, particularly if the milk-handling equipment is not regularly and properly sterilized. During long runs these organisms may on rare

occasions develop in pasteurizing equipment to the extent of greatly increasing bacterial counts in the pasteurized product.

Thermoduric or heat-resistant forms of bacteria, which do not grow at pasteurization temperatures but may survive such treatment, are quite commonly found in Eastern milk supplies, but the true thermophilic types appear to have greater incidence in the Central Western milks.

The causative microorganism of tuberculosis, *M. tuberculosis,* has a high resistance to heat compared with the other pathogens found in milk. It has therefore been given much consideration in decisions regarding proper pasteurization temperatures.

The following data relative to the tuberculosis bacilli are given by Park.[1]

TABLE 86.—THERMAL DEATH POINT OF THE TUBERCLE BACILLI IN MILK

155°F.	1 minute
145°F.	6 minutes
142°F.	10 minutes
140°F.	15 minutes
138°F.	20 minutes
136°F.	30 minutes

A temperature of 140°F. for 20 minutes destroys *M. tuberculosis* in milk uniformly when every particle of the milk is exposed to that temperature. A safety margin of at least 2°F. and 10 minutes is allowed in commercial pasteurization to insure the destruction of *M. tuberculosis* and other pathogens.

The formation of foam on the surface of milk in a pasteurizer may enable a part of the milk to escape proper pasteurization unless the air above the milk is heated at least to pasteurization temperature and precautions must be taken to insure that all the milk does reach proper temperatures.[2]

The efficiency of pasteurization, to which much attention was paid in earlier days, was based on the percentage reduction in bacterial counts obtained after the process was completed. It is apparent that the important consideration in respect to pasteurization is the numbers and types of organisms which survive the process rather than what percentage are killed.

Regardless of what equipment may be used in the pasteurizing of milk or how perfect it may be in design, the success of the process in making milk safe for the consumer is dependent to a considerable extent on the human element, especially in respect to those who have as their responsibility the proper maintenance of temperature control.

[1] PARK, W. H., Thermal Death Points of Pathogenic Bacteria in Milk. *Am. J. Pub. Health,* **17**, 36–47, 1927.

[2] WHITTAKER, ARCHIBALD, and MILLER, *U. S. Dept. Agr. Tech. Bull.* 18, 1927.

Numerous arguments of varying weight have been presented against the process of pasteurization, but despite this fact, the value of this process, when properly conducted, as a protection to the health and safety of the consumer far outweighs all adverse criticisms, and no other procedure that is available offers a comparable insurance against transmission of disease by milk.

Holding Method.—The holding method involves the use of vat, pocket, continuous flow, or in-the-bottle pasteurizers, and consists in heating milk to pasteurizing temperature (142 to 145°F.) and maintaining that temperature in a suitable holder for a period of at least 30 min-

FIG. 37.—Stainless steel pasteurized for milk. (*Courtesy Food Industries.*)

utes, followed by a rapid cooling to 50°F. or lower. Here it may be observed that 40 to 45°F. is far better as a temperature to be attained as many bacteria will grow, at first slowly and later rapidly, at 50°F. The rapid cooling should be immediately followed by refrigeration until the milk is delivered. The holding method of pasteurization is the most widely used method in the United States and many states and municipalities recognize no other means. Much attention has been directed toward all the methods of pasteurization in the past decade and rapid strides have been made in the engineering aspects since 1925, when an investigation of commercial pasteurization was conducted by the U. S. Public Health Service.[1] A program inaugurated soon thereafter for the study and correction of defects in pasteurization equipment has been helpful in

[1] See NORTH, PARK, MOORE, ROSENAU, ARMSTRONG, WADSWORTH, and PHELPS, Commercial Pasteurization, *U. S. Pub. Health Bull.* 147, 1925.

influencing the design and construction of equipment in many pasteurizing plants. Precision of temperature has become an accepted responsibility, by both the dairy industry and manufacturers of dairy equipment, with the result that no method of pasteurization is acceptable to health authorities which does not maintain with accuracy a temperature of

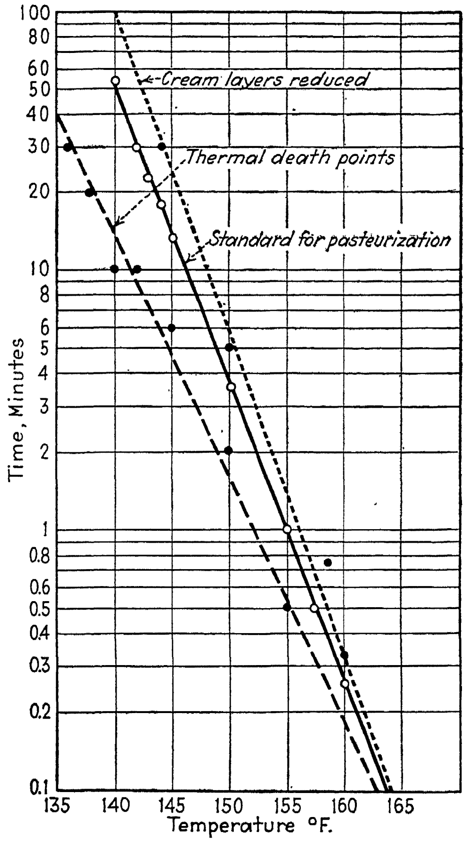


FIG. 38.—Comparable pasteurization standards for milk based upon the minimum periods required to destroy the tubercle bacillus and the maximum time that milk can be held at given temperatures to give the smallest reductions in cream-layer volumes that could be detected with certainty from several tests.

every particle of milk within 1°F. throughout the entire pasteurizing process. Such delicate precision has become necessary not alone from the standpoint of safety but also because temperatures above 144°F. may adversely affect the cream line of the milk, a matter which affects neither the safety nor the food quality of the milk.

As there is, however, concern on the part of the milk dealer about the possible changes and impairment of cream-layer volume on one hand and

concern by health authorities as to the margin of safety over the exact time necessary to kill the tubercle organism, the graph (Fig. 38), by Dahlberg, taken from the New York State Agricultural Experiment Station Technical Bulletin No. 203, is of interest. This graph makes possible certain comparisons, resulting from the work of Dahlberg and others,[1] concerning the relation of maximum periods of time which milk could be held at various temperatures to the least measurable reductions in cream-layer volumes. It also supplies data on the thermal-death periods of tubercle bacilli. As straight-line relations were evident in both cases, Dahlberg was able to make certain comparisons. His general conclusions were as follows:

> The variations between the thermal death points of the tubercle bacillus in milk and the thermal cream-layer impairment time were greatest at the lower temperatures. Thus, at 142°F. the variation in time between the two sets of data is 41 minutes, while at 160°F. the time variation is only 9 seconds.
>
> Accepting 142°F. for 30 minutes as the proper pasteurization standard, a series of standards were calculated which were comparable from the standpoint of margins of safety in protecting the public against disease organisms in milk and in safeguarding good creaming properties. While the total time variation became less with increased temperatures of pasteurization, the time required to destroy the tubercle bacillus was exceeded at each temperature by the same percentage of the total variation in time. On this basis milk should be pasteurized at 145°F. for 13 minutes and at 160°F. for 16 seconds.
>
> Pasteurization at 142°F. permitted a maximum time variation of 20 minutes while 160°F. gave a safety period of 5 seconds. On the other hand, if the holding time was exactly 30 minutes, the maximum temperature variation was from 136 to 144°F., but at exactly 16 seconds holding the temperature variation was from 159 to 161.25°F. The time required to heat milk to high temperatures is an important factor to consider in the holding period with certain types of equipment.

Effective and accurate pasteurizing has been made possible largely through the development of precision heaters using a *heating* water medium having a temperature only 1 or 2°F. higher than that of the milk being heated. This heating is accomplished by increasing the area of heating surfaces or greatly increasing the water circulation, or both. It has been recommended that a ratio of at least 7:1 of the heating water to the milk flow should be maintained for optimum results. The use of hot-water sprays has also proved helpful in obtaining more accurate temperature control in some types of pasteurizing apparatus. More attention has been paid also to the metals used in construction, methods of agitation, valves, and thermometers in recent years.

The following regulations are cited in the Public Health Service Ordinance in order to accomplish the desired results.

[1] *New York State Agr. Exp. Sta. Tech. Bull.* 180, 1931.

U. S. Public Health Service Milk Ordinance and Code (1935)

Maintenance of Pasteurization Time and Temperature—Maintaining Minimum Legal Pasteurization Temperature.—The pasteurization equipment shall be operated so that the indicating thermometers and the recording thermometer charts both read at least the temperature which the definition of pasteurization requires the thermometers to show, continuously throughout the holding period. The indicating and not the recording thermometer shall be used as an index of temperature by the plant operator. The temperature shown by the recording thermometer shall be checked against the temperature shown by the indicating thermometer daily by the plant operator, and at least biweekly by the health officer, and the recording thermometer shall be kept adjusted so as at no time to read higher than the indicating thermometer.

The health officer shall accept only designs of equipment which have shown on official test a deviation between the hottest and coldest particles of milk or milk products of not more than 1°F. For all existing installations provided with agitation devices, and for all new vat, tank, and pocket-type holders, *agitation* throughout the holding period shall be required; provided that in the case of vat, tank, or pocket holders in which the milk is brought to the final pasteurization temperature before entering the holders, agitation may be omitted if the lowest portion of each holder is provided with or is in contact with a jacket through which is circulated a heating medium thermostatically controlled, and provided that bulbs of both an indicating and a recording thermometer shall be located in the heating medium downstream from the point of its discharge from the jacket, and provided further that both the indicating and the recording thermometers shall indicate throughout the filling, holding, and emptying periods at least the temperature found necessary, by tests made on that particular model of holder and acceptable to the State health department, to prevent the temperature of the coldest particle of milk in any holder during the holding period from falling below 143½°F. when the atmospheric temperature of the pasteurization room is 55°F. or less.

All apparatus in which the milk or milk products are brought to the final pasteurization temperature before entering the holder, and in which the holding time is automatically controlled, or is manually controlled but with no means provided for heating the milk in the holder, shall be equipped with a dependable thermostatic control of the milk temperature and with an automatic *milk-flow stop*. Automatic milk-flow stops are devices for preventing the entrance of milk of sublegal temperature into holders, and include automatic milk-pump stops (which automatically start and stop the milk-pump motor at predetermined milk temperatures) and automatic flow-diversion valves (which automatically divert the flow of milk into or away from the holder at predetermined milk temperatures). Either of these may be used, except that an automatic flow-diversion valve is mandatory for the following installations, unless a milk-pump stop is installed and operated as herein provided and the pipe connecting the heater and the holder is drained immediately following each stopping of the milk pump: (1) 30-minute holders which are not equipped with agitation devices to mix the incoming milk with all the milk in the holder; and (2) 30-minute holders which,

though equipped with agitation devices to mix the incoming milk with all of the milk in the holders, are so arranged that the milk between the outlet of the heater and the inlet of the most distant holder will be sufficient in quantity, when cooled to 70°F. (room temperature), to lower the final temperature of the milk in the holder to below 143½°F.

If an automatic milk-pump stop is used it shall be located at the outlet of the heater. This device should be so connected as simultaneously to stop all milk pumps in the system which would be likely to cause overflow if operating when flow to the holder has stopped. This is better than to stop automatically only the milk pumps for the holder proper and depend upon manual operation of a switch for any other milk pumps in the system.

If an automatic flow-diversion valve is used, it shall be located at the holder inlet with the control bulb for the valve located in the pipe line as close to the valve as is practicable. In installations open at any point upstream from the heater, such as those using a surface-type regenerator the milk flow can be diverted back to the unpasteurized milk at the open point. In such cases some provision will be required for taking care of the additional milk coming to that point. This may be accomplished by a float-operated valve controlling the raw-milk supply. If a float-valve arrangement is not used, some warning signal, such as a bell or a horn, will be necessary to warn the operator that the milk flow is being diverted away from the holder, and thus enable him to shut off the pumps in case there is a likelihood of overflow. In closed-system installations the milk flow may be diverted back to the suction side of the pump forcing the milk through the heater. This diversion line may contain some milk at all times. When there is a positive head on the suction side of the pump a low-point drain valve may be placed in this line, also a check valve where the line connects into the pump suction. With this arrangement of valves the operator, if he so desires, may drain the diversion line.

The milk-flow stop shall be so designed as to insure automatic starting. The electrical system comprising the milk-flow stop, the milk-pump motor or the diversion-valve mechanism, as the case may be, and their connections shall be designed so as to make it impossible to start the flow of milk into the holder unless the bulb of the milk-flow stop is at or above the legal pasteurization temperature. The milk-flow stop bulb shall not be removed from its proper position during the pasteurization process.

The milk-flow stop shall be so designed as to make it impossible for the plant operator to lower the temperature at which it operates without the knowledge of the health officer. This may be done by means of a seal, which shall not be broken by the plant operator without promptly notifying the health officer.

The milk-flow stop is intended as a safety feature and not as a part of the routine temperature-control equipment. The routine operating milk temperature shall be sufficiently above the setting of the milk-flow stop so that the latter will not be brought into frequent operation.

The milk-flow stop shall be so adjusted that the flow of milk into the holder will stop before or when the legal temperature of pasteurization is reached during descending temperatures and will not start before the legal temperature of pasteurization is reached during ascending temperatures. The accuracy of the

cut-out and cut-in responses shall be tested daily by the plant operator at the beginning of the day's run and at least monthly by the health officer, and entered upon the recording thermometer chart. This test may be made by starting the run with water which is then heated to above pasteurization temperature by opening the steam by-pass valve, then cooling the water to below the pasteurization temperature by turning off the steam supply, and noting the reading of the heater outlet indicating thermometer at the instant the cut-out response occurs, then gradually reheating the water to above the pasteurization temperature by reopening the steam by-pass valve, and noting the temperature at which the cut-in response occurs.

PASTEURIZERS

The vat pasteurizer consists of a tank or vat provided with some means of heating the milk held therein. Agitators for keeping the milk in motion are essential as are thermometers for both the determination and recording of the milk temperature. The actual milk container which is fitted with inlet and outlet connections may be within an outer tank, enabling the use of the space between the two for the heating medium. Such vats differ widely in shape, design, and capacity. They are all provided with covers to prevent evaporation and keep the temperature above the milk at the desired level.[1]

There are several means by which the milk may be heated. In some cases the heat is obtained by forcing hot water through a hollow coil which is within the holding container. Live steam may be used in jacketed tanks constructed of metal with glass or enameled lining. In some the space between outer jacket and inner vat may be filled with hot water which is both heated and agitated by steam jets. The heating medium is designed in certain types to flow down the outer sides of the inner jacket while in others the previously heated water is sprayed in large quantities against the sides. Regardless of the method used, care must be exercised to insure the fact that all the milk reaches the proper temperature and is held at that temperature for the prescribed period. Many of the types of pasteurizers now on the market offer very accurate mechanical control of temperature. The agitation of the milk may be accomplished by mechanical paddles or by revolving mechanical coils.

In some pasteurizers the milk is brought up to the required temperature in the vats while in other instances the milk is preheated in a regenerator to practically the temperature of pasteurization before entering the vat. After the pasteurization the milk is immediately conducted to coolers. It is possible to cool the milk in the vat to a slight extent if a refrigerant is used in place of the heating medium, although it is more common practice to run the milk from the vat to special coolers.

[1] See Grant and Clement, Small Plants for Pasteurizing Milk, *U. S. Dept. Agr. Circ.* 214.

Continuous-flow Pasteurizers.—In contrast to the pasteurizers discussed previously which must be filled, brought to temperature, held for the required time and then completely discharged, there are others which utilize the principle of continuous flow. The milk is confined to a long slender channel, usually a series of pipes or coils and the milk is forced through the system at a controlled rate of flow. These pipes are usually enclosed in a cabinet which is maintained at the necessary temperature by means of steam as a heating agent. Such an arrangement provides a continuous process and eliminates the possibility of short circuits or the accidental removal of milk which has not been properly pasteurized. By maintaining a slight positive pressure on the milk the contamination of the pasteurized milk by the heating water in case of leakage is averted.

Another type of pasteurizing equipment sometimes used is an automatic holder consisting of a number of separate vertical compartments capable of being filled and emptied automatically and independent of each other. This type of pasteurizer shortens the filling and discharging time utilized by a single large holder tank of equal capacity to that of the combined smaller units, which may be eight in number. Thus this type of pasteurizer tends to minimize the possibility of extra holding of milk at pasteurization temperatures, which may affect the cream line unfavorably. The entire equipment is heated by steam and included within an insulated shell.

Pasteurizing in the Bottle.—A less commonly used method of pasteurization is that of filling the bottles, capping, pasteurizing in the bottle by hot-water exposure, and cooling in the bottle, which is then ready for delivery. This method has the advantage that the milk cannot be contaminated by handling after being pasteurized. Very large equipment of this sort is used in some milk plants which apply heat treatment in this manner. From an expense standpoint, extra heat and refrigeration are needed as the bottle as well as the milk must be heated and cooled. Bottles of a different capacity and type than ordinarily used are needed to take care of the expansion of the milk during heating and to prevent breakage, and special care is essential that the caps do not leak. Such bottles appear as underfilled to the consumer, who is likely to look on them with suspicion until educated to the extent of knowing that a full quart of milk is still present.

High-temperature, Short-time Pasteurization.—In the latter part of the past century, the so-called flash pasteurization was introduced as a method of pasteurizing milk. This process gained some popularity in the United States during the first of the present century. It consisted mainly of rapidly passing milk over metal surfaces heated by steam to temperatures varying from 160 to 185°F., for very short periods of time, followed by immediate cooling.

Flash pasteurization was viewed with disfavor by numerous health officials because of lack of uniform and accurate temperature control and in some instances, improper use of effective temperatures. Good results were obtained when the metal surface was bright, but milk protein often burned on and then the efficiency dropped. In addition, the uneven heating of milk in some of these early methods was likely to cause overheating of certain portions of milk and underheating in others with a resultant effect on the cream line which was unsatisfactory to the milk dealer. Recent years have evidenced a definite trend toward renewed interest and confidence in short-time, high-temperature pasteurization, owing chiefly to the substantial improvements in equipment and in temperature control which have been developed.[1]

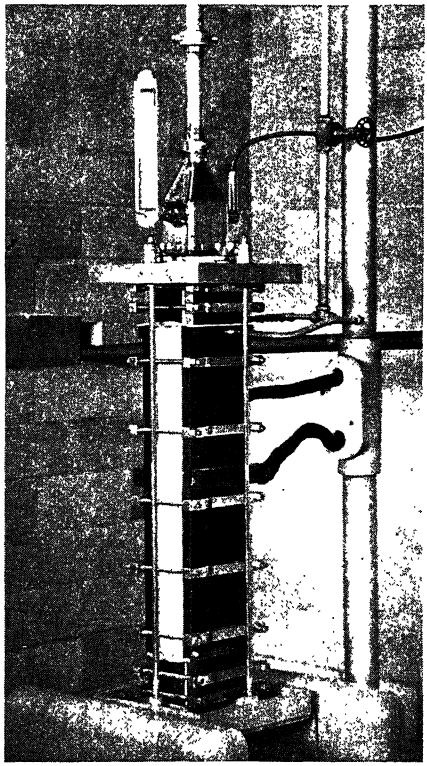


Fig. 39.—Electropure heater. (*Courtesy The Milk Plant Monthly.*)

One method using electricity as a heating medium is now used in several states. The raw milk is pumped through a regenerative heater-cooler which raises the temperature to 120°F. and then through a rectangular heating chamber, two opposite sides of which are terminals or electrodes about 3 or 4 in. apart. The other two sides are of glass or hard rubber. An alternating current of 60 cycles is used. As the milk passes through this chamber, the resistance of the milk to the electric current quickly raises the temperature to 161 to 162°F. This change in temperature is brought about in 10 seconds. The electrodes in this system are cooled on the outside by a stream of cold water in order to prevent milk from sticking to the inside of the electrodes. An electrical thermostatic temperature control with the bulb in the outlet pipe is connected to the milk pump so that the rate of milk flow is increased if the temperature goes above 162°F.; and if the temperature of the milk reaches 161°F., the speed of the pump is automatically decreased so that the temperature may be maintained within 1°F. and a nearly constant flow

[1] Prescott, S. C. *Am. J. Pub. Health,* **17**, 221, 1927.

results. If for any reason the temperature of the milk drops to 160°F. or below, the pump stops and an alarm light or bell is operated to attract the attention of the operator. During the periods of operation an automatic temperature-recording device is used to record the temperature of the milk on a chart as is the case in all types of pasteurizing equipment.

This method of destruction of bacteria in milk, which is due to thermal effects, has been followed by the development of other thermal methods using hot water rather than electricity as a heating medium. All such methods involve the use of temperatures of approximately 160°F. and a holding period of 15 seconds and employ very precise temperature and flow-control apparatus.

In 1931 the Committee on Milk Supply and Control of the Public Health Engineering Section of the American Public Health Association and the Committee on Milk Sanitation of the Conference of State Sanitary Engineers[1] made a study of several types of high-temperature, short-time pasteurizers and concluded:

I. The operation of such pasteurizers should not be difficult in the hands of intelligent operators, as they are relatively simple in construction and easy to clean and sterilize.

II. They are reliable and built for fixed, minimum holding periods which it would be difficult to change without deliberate fraud.

III. The pump stop control operates effectively to stop the milk pump and the flow of milk in the event of a drop in temperature below a predetermined point.

In a review of the literature in 1933, Yale stated in conclusion: "Thorough studies by competent investigators in this country on modern improved types of high-temperature, short-time, and 30-minute holding pasteurizers, indicate that both methods are effective in providing a safe milk supply."[2]

NOTE: For a more complete description of high-temperature, short-time pasteurizers see the 9th Annual Report of the Pennsylvania Association of Dairy and Milk Inspectors, Report of the Committee on Pasteurization, 1933. Chairman, R. E. Irwin.

The Cream Line.—Cream contains a large proportion of the fats present in the milk from which it originates, together with a portion of the milk serum and its constituents. Because of its high fat concentration, cream has more color than the remainder of the milk from which it has separated after standing, and a fairly sharp line of demarcation is apparent if milk has been allowed to remain in a state of rest for some time. This level, or this "cream line," in bottled milk is often used by the consumer as a criterion of quality.

[1] This report is published in the American Public Health Association Year-Book, 1931–1932, pp. 112–125. C. A. Holmquist, Chairman of the Committee.

[2] YALE, M. W., Laboratory Section Report, 26th Annual Convention, International Association of Milk Dealers, 1933.

Because of this fact, much consideration has been given to those physical influences which may affect the cream line in milk. These factors include the age of the milk; the amount of agitation, transportation, and other handling it receives at low temperature previous to pasteurization; the pasteurization temperature and the period of time it is held at that temperature. Prolonged holding at high temperatures such as those levels used for pasteurization tends to reduce the apparent cream volume. The same is true when holding temperatures higher than 144°F. are used for the usual pasteurization time of 30 minutes. Excessive handling while cold has the same effect. Milk which has creamed once and is subsequently disturbed recreams slowly and imperfectly. Warming such milk and recooling are sometimes helpful in restoring creaming ability.

Construction of Pasteurizers from a Sanitary Standpoint.—All pasteurization equipment requires careful and constant cleaning and for this reason must be so constructed that it may be thoroughly and easily cleaned. The design should facilitate taking the equipment apart so that all surfaces may be reached for mechanical scrubbing with proper detergents, followed, after reassembling, by sterilization. The pasteurizer might well be considered the heart of any milk plant as any inefficiencies will diastrously affect the entire system. Thermal efficiency in the equipment is highly desirable from the standpoint of safety, quality, and economy.

Cooling.—After pasteurization has been properly completed it is essential that the milk be immediately reduced to refrigeration temperatures, preferably below 50°F. This is frequently done by the use of regenerative coolers, with pasteurized milk from which the heat must be removed passing in pipes or tubes countercurrent to the flow in the outer surrounding pipes containing raw milk which is being simultaneously warmed previous to pasteurizing. Subsequently the milk must be further cooled by refrigerated water, ammonia (NH_3), or brine. This may be done in enclosed systems or by vertical-surface coolers over which the milk is allowed to run, and enclosed to protect the milk from air contamination.

Bottling.—The final step in the process, except when milk is pasteurized in the bottle, is to bottle the cooled milk in clean bottles which have been rigorously cleaned, heated, and subjected to conditions which reduce bacterial contamination to a minimum. Some certified-milk plants actually sterilize all bottles before filling. The bottling equipment in all plants of any size is done mechanically and in even the smallest dairies every precaution should be taken to prevent contact of the pasteurized milk with human hands because of the concomitant possibilities of bacterial contamination. The bottling machines may be of two types,

those operating by gravity or those which cause a vacuum in the bottle which facilitates filling. The filled bottles are immediately capped automatically with a single cap or sometimes double caps, to prevent future bacterial contamination. The use of caps which completely cover the orifice and rim of the bottle are preferable in every respect, and the time is probably not far distant when such caps will be required for all bottled milk. They are now required in many cities or states for the higher grades.

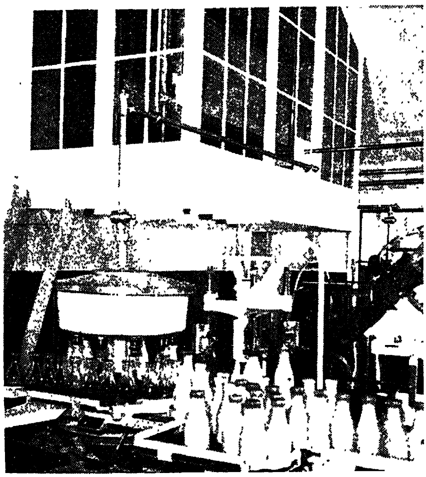


FIG. 40.—Bottle filling equipment. (*Courtesy Food Industries.*)

Bottle Washers.—If the milk bottles have not been thoroughly cleaned, the milk contained therein may be unsafe for consumption, even though it has been carefully pasteurized previous to filling. The equipment used for bottle washing in larger milk plants is not only intricate but costly. It involves the mechanical soaking, scrubbing, heating, and practical disinfection of each bottle of many thousands which may undergo cleaning in an hour, followed by rinsing, draining, and visual inspection by the employees for residual defects, cracks, etc. The use of proper detergents, their maintenance at sufficient concentrations, and uniform temperature control must be carefully supervised for the desired results.

Stassanizing or Stassanization.—Reference has been made in recent years to a so-called new principle of heating and processing milk, resulting from the work of an Italian, Henri Stassano, who developed a regenerative enclosed method of heating milk under slight pressure in a thin layer between two heated surfaces. The milk is heated to 167°F., which is claimed to be the equivalent of 194°F. by the usual flashing methods, with practically no milk-stone formation. Less destruction of vitamins, greater economy of heat and destruction of 99.4 to 99.9 per cent of the bacteria are said to be the advantages offered by this method.

Grindrodization.—A steam impact process of milk heating and sterilizing has been developed which is known as "Grindrodization" or "Grindrod Steam Impact Sterilization" and is named after its inventor.

The apparatus involved consists generally of an enclosed hot well in which the product is first evacuated and then rapidly heated with live steam distributed by a multiple jet which provides tiny needle-like impingements at various angles into the mass of material under treatment.

This imparts a rotating motion to the mass under treatment thereby affording considerable surface exposure to the action of the distributed steam. The introduction of live steam gradually displaces the vacuum until a positive pressure of approximately 7 lb. and a temperature of

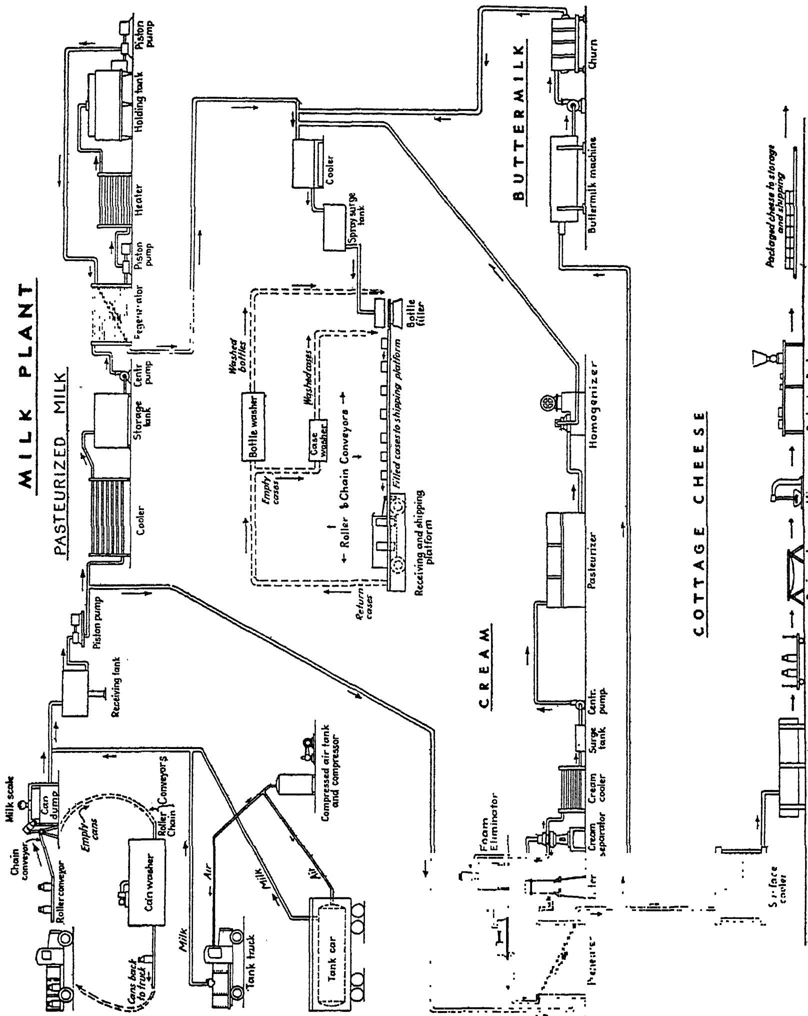


FIG. 41.—Flow sheet of dairy operations. (*Courtesy Food Industries.*)

230°F. is attained. This temperature and pressure are generally maintained for a period of 2 to 3 minutes after which the product is passed directly into a vacuum pan for rapid cooling and evaporation of the water condensed in the treated mass during the sterilization procedure.

Vegetative cells and hemolytic streptococci are said to be practically all destroyed at 230°F. for 1 minute, while about 10 per cent of the spores

survive after 2 or 3 minutes' treatment. While the process provides very effective and efficient means of heating, it destroys the creaming property of milk, gives a slight cooked flavor as well as a slight precipitation of albumin. It would appear that the most likely application of this process to dairy products lies in the sterilization of milk to be used for culturing the fermented milks such as acidophilus milk, bulgaricus milk, and for the preparation of cream for ripening.

INFLUENCE OF OXIDATION

The Development of Tallowy Flavors in Milk and Cream.—In recent years, the adoption of milk-grading systems and the development and establishment of high standards in sanitary practices have resulted in marked improvement in the bacterial quality of raw milk. With this improvement, however, there have been noticeable tendencies for the development of tallowy flavors in market milk. This defect has been more evident in the milks of high quality such as certified and Grade A milks.

Tallowiness in milk has been described by various terms and the lack of uniformity in the matter of flavor nomenclature has led to some confusion.[1] Such terms as oily, cappy, papery, oxidized, storage, and doubtless others have been used. Metallic and astringent are also terms that have crept in and are doubtless flavors that are oftentimes associated with tallowiness, but such is not the case with rancid bitter flavors. Tallowiness is a flavor defect which is recognized as being due to the oxidation of butter fat, whereas rancidity is a separate and distinct defect due to fat hydrolysis.[2]

Normally, rancid bitter flavors are the result of progressive influences which occur when samples of milk freshly drawn from the udder are allowed to age and acquire a "cowy" taste. Furthermore, in such milk, the development of the rancid bitter flavor is simultaneous with an increase in titratable acidity. This increase in titratable acidity has been found not to be a true lactic type but increases as the development of the rancid flavor advances. An association between the increase in lipase activity and the chloride content of milk in the late stages of lactation has been indicated by some workers. They also observed that milks high in chloride content showed the greater increases in nonlactic acidity, and offered data which suggest that the objectionable increase in nonlactic acidity of raw cream with its attendant development of the bitter rancid flavor can be minimized, or possibly eliminated, by excluding milks high in chloride content as sources of raw-cream supplies.

[1] GUTHRIE, E. S., and H. J. BRUECKNER, *Cornell Univ. Agr. Sta. Bull.* 606, 1933.
[2] SHERMAN, J. M., *Cornell Veterinarian*, **25**, 202, 1934.

There is considerable evidence that the development of rancid bitter flavors is due to fat hydrolysis and not to oxidation. Lipase activity due to enzymes can be prevented by heating the milk to 142°F. The development of rancid flavors can be enhanced by homogenizing the raw milk at low temperatures, possibly because in so doing a greater surface is exposed to the action of the agents responsible for hydrolysis. Additional evidence is found in the fact that oxidation-reduction potential measurements indicate that oxidation plays no part in the development of this flavor defect. An antagonistic reaction between the agents of tallowiness and of rancidity in raw milk or cream containing copper salts has been shown to exist. In the development of tallowy flavors, metal contamination has been found to be an important cause of such defects but the present greater occurrence of tallowiness in milk cannot be attributed solely to such influence. If metal were the important factor, the troublesome cases of tallowiness found to exist in dairy plants where the equipment is especially arranged and constructed to avoid metallic contamination could not be adequately explained. Tracy and Ruehe[1] have shown that tallowiness is more prevalent in winter than in summer. In a report by Tracy, Ramsey, and Ruehe,[2] data were presented which showed that milk contaminated with copper is more likely to become tallowy if stored immediately at 40°F. than if held at higher temperatures such as 68 to 90°F. for 1 to 6 hours before being brought to 40°F. Furthermore, incubation of cream to which copper had been added raised the score of the resultant butter 3½ points, while cream held at room temperature for one to two days resulted in butter free from tallowiness, yet butter made from the same cream stored immediately at 40°F. was very tallowy. Bacteria and yeasts were found to play an important role in preventing tallowiness development, and it is evident from the results of these workers that oxidation-reduction potentials are related to fat oxidation. Microorganisms were found to have reducing influences, as evidenced by the change in potential toward the reduction phase. Presumably a removal of oxygen occurs through the metabolism process of the organisms which would explain why milk of very good quality, from bacterial considerations, is more likely to become tallowy than milk more highly contaminated. Frazier and Whittier[3] have studied the effects of various pure cultures of bacteria upon the oxidation-reduction potential of milk. They found that each organism produced characteristic potentials peculiar to particular species. They found that *Escherichia coli*, *Escherichia communior*, and *Aerobacter aerogenes* when grown with *Streptococcus*

[1] Tracy, P. H., and H. A. Ruehe, *J. Dairy Sci.*, **14**, 250–267, 1931.

[2] Tracy, P. H., R. J. Ramsey, and H. A. Ruehe, *Illinois Agr. Exp. Sta. Bull.* 389, 1933.

[3] Frazier, W. C., and E. O. Whittier, *J. Bact.*, **21**, 239–251, 1931.

lactis, all exerted a restraining influence upon the rapid drop in Eh values usually caused by pure cultures of *Streptococcus lactis*.[1]

DAIRY CLEANLINESS AND DETERGENTS[2]

The importance of safety and cleanliness in the production of milk has been increasingly stressed with the advent of bacteriological control over milk supplies. While surgical sterility in dairy apparatus is not practicable, physical cleanliness is essential and its attainment requires not only diligent but also intelligent care in cleaning all equipment in which milk is collected, refrigerated, transported, pasteurized, or stored. It needs also an understanding of detergents themselves if one is to carry out this important function with efficiency and economy.

The use of proper detergents depends on a number of factors, among which are the following:

1. Physical and chemical character of the "dirts" to be removed.
2. Hardness or chemical quality of water used for washing.
3. Possible corrosive effect of detergents on metals.
4. Temperature conditions under which detergent is used.

The "dirts" that dairy detergents normally are expected to remove, or prepare for removal by subsequent mechanical processes, are:

A. Particles of milk solids held to surfaces by oily or greasy binders. This type of uncleanliness involves emulsion of the oily or greasy binder of milk fat.

B. Milk solids held by adsorption to surfaces, which require adsorption of the "dirt" or milk solids by the detergent.

C. So-called milk-stone deposits (calcium phosphate and protein) accumulated on surfaces subjected to intense heat applications. This type of deposit should be combated by preventive methods through proper use of detergents.

Dairy detergents used for cleansing purposes in dairy plants may be classified in the following groups, outlined by Zoller.[3]

1. Alkalies (pure):
   - Sodium hydroxide (caustic soda).
   - Potassium hydroxide (caustic potash).
   - Ammonium hydroxide (ammonia).
2. Alkali salts or buffered alkalies:

[1] *Ibid.*, 253–262, 1931.

[2] Parker, M. E., Detergent Properties of Alkaline Dairy Washing Compounds, *Am. J. Pub. Health*, **19**, 571, 1929.

Parker, M. E., and Johnson, Notes on the Prevention and Removal of Milk Stone, *Proc. Intern. Assoc. Milk Dealers*, 1930.

[3] Zoller, *Proc. Intern. Assoc. Milk Dealers*, 1928.

a. Simple water-soluble group:
  - Sodium bicarbonate (baking soda).
  - Sodium carbonate (soda ash).
  - Ammonium carbonate.
  - Potassium carbonate.
  - Trisodium phosphate.
  - Sodium tetraborate.

b. Colloidal group:
  - Silicates of sodium and potassium.
  - Aluminates.
  - Soaps.

The particular task at hand will dictate in many instances the most suitable type of detergent which should be chosen, as the alkalinity of the detergent solution and the temperature conditions under which the solution must be used are important factors. Regardless of the solution chosen, its use should be considered as only a preliminary to the subsequent complete mechanical removal of all "dirt" by mechanical action, either through the use of revolving brushes, hand brushes, hydraulic pressure, or similar methods. After such mechanical or manual operations are completed, the rinsing processes or chemical sterilizations are carried out with greater effectiveness.

The hydrogen ion concentration of some detergent solutions, as well as the concentration of undissociated salts in solution, have been found to be important factors from the standpoint of the germicidal action of dairy detergents.

Certain chemical compounds have come into wide usage in the so-called chemical sterilization of dairy equipment and utensils, although the use of such materials should not and cannot be satisfactorily substituted for proper cleaning processes. The majority of such compounds which have proved well adapted to the dairy purposes contain chlorine, and among these chemicals used are calcium hypochlorite, sodium hypochlorite, sodium hypochlorite-disodium phosphate, chloramine T, and chlorine gas compressed in steel cylinders. The bactericidal action of such compounds is primarily dependent upon the concentration of active or available chlorine which they are capable of liberating in solution, and their effective application in dairy cleansing operations depends on the careful control of the active chlorine content.

As alkalies are necessary in the cleaning of dairy equipment and utensils, some consideration must be paid to the action of alkalies upon metals. The so-called "stainless steels" have been perfected in recent years and the use of chromium-nickel steel and chrome steels have become quite common in the construction of dairy equipment. These alloys are corrosion-resisting when subjected to proper hardening and

polishing and for this reason are likely to attain wide usage in dairy equipment. Their expense is likely to limit the use of these alloys in respect to dairy utensils.

Aluminum products are subject to intense corrosive action by alkaline solutions. Copper, iron, galvanized iron, and zinc are all extensively corroded by the action of alkalies but not so severely as tin-plated metals.

The corrosion of tin-plated metals may be greatly reduced by using trisodium phosphate with a small amount of sodium chromate. The corrosive effect of alkaline detergents on aluminum may be avoided by using sodium carbonate with a small amount of sodium silicate.

Metals are known to exert considerable effect on the flavor of milk. Among those metals which are said to produce definite off-flavors under certain circumstances are brass, bronze, copper, nickel bronze, nickel silver. Poorly plated copper or copper alloys or metals on which these platings have worn thin may have the same effect. Those metals showing no appreciable effect on the flavor of milk include aluminum and chrome-nickel steel; also tin- or chromium-plated metals, if the plating is in proper condition. Nickel may be included if in contact with cold milk only. Glass and enameled ware do not give objectionable flavors to milk and therefore have been used for certain dairy purposes.

The undesirable flavors, produced in milks by contact with metals, have been characterized in the following terms: astringent, papery, metallic, oily. All are objectionable and must be prevented, if possible.

VITAMIN D MILKS

Because of the fact that ordinary cows' milk is not a dependable source of vitamin D in sufficient quantities to prevent rickets in infants, methods have been devised to increase this content. There are three different methods which have attained commercial utilization in this respect up to the present time.

One of these depends on the irradiation of milk by subjecting it to exposure with ultraviolet light. Another method involves the addition of irradiated yeast in known quantities to the diet of the producing cow. The third process involves the addition of a cod-liver-oil concentrate to the milk.

Each of these methods has been reported as capable of increasing the antirachitic effect of milk when used in the treatment of laboratory animals as well as in the treatment of infants.[1] The laboratory animals are commonly used as a means of calibrating the vitamin potency of

[1] See J. W. M. Bunker and R. S. Harris, The Clinical Status of Vitamin D Milks, *New Eng. Jour. Med.*, **211**, 1140, 1934, for a review of the clinical information concerning Vitamin D milks to that date.

various samples and the protective values are expressed in terms of U.S.P. vitamin units.[1]

Irradiated Vitamin D Milk.—Direct irradiation of milk to increase its vitamin D content is the result of experimental work by Dr. Steenbock of the University of Wisconsin, which has been extended in many directions in the past decade. The process is protected by patents now held by the Wisconsin Alumni Research Foundation and involves a short exposure, usually not more than 4 to 6 seconds, of the milk in a thin film to a reliable source of ultraviolet light, usually a carbon arc lamp. Units designed for this type of irradiation activate the provitamin cholesterol normally present in milk. They may be of the flat type, in which the milk flows down over a series of coils by gravity and is exposed to lamps equipped with reflectors which focus the rays on the milk film, or may be of the drum type in which the milk is fed at a predetermined rate to a distributing trough at the top of a cylindrical irradiator. In the latter method the milk flows down the inside of the tapered inner wall of the cylinder in a thin film and is exposed to the light, the source of which is suspended from the top center of the cylinder, thereby obviating the need of reflectors as the cylinder may serve in that capacity. Milk irradiated in this manner is usually so treated that it contains a standard quantity of at least 135 U.S.P. units per quart.

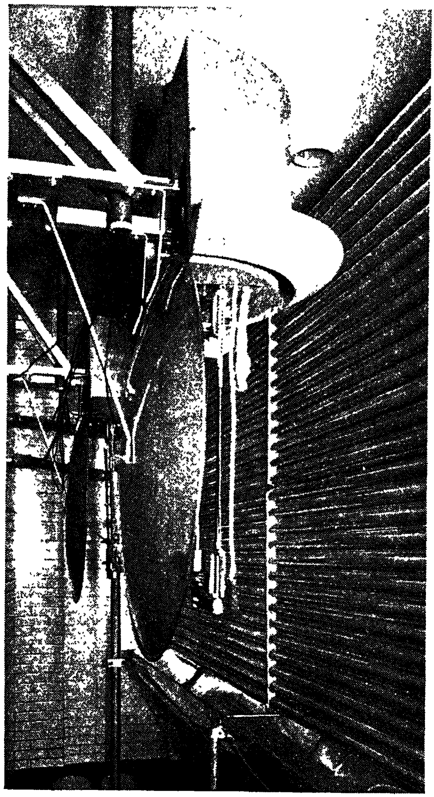


Fig. 42.—Cherry-Burrell 12,000 lb. irradiating outfit, 4 "U" lamps. Borden Farm Products Company of Illinois, Hamilton Park plant, Chicago. (*Courtesy Food Industries.*)

Metabolized or Yeast-fed Milk.—When the cows are fed irradiated yeast as a means of increasing the vitamin D content of the milk, the diet

[1] One U.S.P. unit which has been since Jan. 1, 1935, equivalent to the International Standard Unit, signifies the degree of healing equivalent to the effect of one milligram of a standardized solution of ergosterol prepared at the National Institute for Medical Research in London. This is the International Unit of the Permanent Commission on Biological Standards of the League of Nations Health Organization.

of the cows is so regulated that the potency of the resulting milk is standardized at 430 units per quart. Such milk is called metabolized milk. The amount of irradiated yeast fed in the ration of each cow is calculated in respect to the average milk production of the animal.

Fortified Vitamin D Milk.—The method of fortifying milk with vitamin D concentrates is accomplished by adding to milk a definite quantity of the concentrated antirachitic active material obtained from cod-liver oil distributed in a menstruum of cream. Cottonseed oil has also been used as the menstruum. This material is dispersed in the milk previous to pasteurization.

The concentrate is obtained from cod-liver oil by extraction with ethyl alcohol, concentration of the extract by distillation, followed by saponification. By treatment with calcium chloride, insoluble calcium soaps precipitate out carrying with them the active material. By subsequent filtration of the precipitate and extraction with acetone the active substances are obtained. These are further purified by adding ether, washing with alkali and then with dilute acid. The ether is later removed by distillation leaving the concentrate which is ready for use after mixing with cream. The concentrate contains 1,000 or more times the original concentration of vitamin D in the cod-liver oil, so only small amounts are necessary in the milk. The milk is stated to be free of any taste changes from such additions. This process is called the Zucker process, after its inventor.

Each of the above methods is subject to use only by license and those controlling the patent rights have strict regulations designed to keep the vitamin D content at a predetermined standard and allow no abuses of the processes. Milk which is to be sold as condensed, evaporated, or canned milk is now quite commonly irradiated in order to increase its vitamin D content.[1]

[1] BURTON, L. V., *Food. Ind.*, **6**, 342, 1934.

CHAPTER XII

DAIRY PRODUCTS

EVAPORATED AND CONDENSED MILK

The manufacture of concentrated milk in various forms has become an industry of great magnitude. In 1933 more than 2 billion pounds of condensed and evaporated milk and milk products were manufactured in the United States, and had a value exceeding 100 million dollars. Large quantities of these products are exported and in recent years the values of evaporated milk alone have sometimes exceeded 7 million dollars and amounted to over 70 million pounds.

Gail Borden obtained the first American patent for condensing milk in 1856 and established the first factory in Walcottville, Connecticut, since which time the number of plants has grown to about 500, located in more than 20 states. Wisconsin leads in this industry and has over 80 condenseries, but New York, Ohio, Michigan, Pennsylvania, California, and Illinois are also important factors in this industry.[1]

The United States is believed to produce well over half of the world's concentrated milk with the Netherlands as the next producer in order of volume, although producing only about 20 per cent as much as the United States. Switzerland, Denmark, Canada, the United Kingdom, France, and Australia are also producers in lesser quantities[2] and export some quantities. The United Kingdom, the Philippine Islands, the Dutch Indies, India, France, and Cuba are the most important importers.

Condensed and evaporated milks have many uses. In addition to their use in place of fresh milk on the table and as infant foods, they are used for cooking purposes in many homes. In the food industries these products are used extensively in ice-cream factories, in bakeries, in the manufacture of confectionery, and of allied food products.

Sweetened condensed milk differs from unsweetened evaporated milk in that the former has 15 to 18 per cent of sugar added in the processing, which results in a final product containing some 40 per cent of sugar. The sugar added was entirely sucrose, refined cane or beet sugar, previous to Dec. 26, 1930, but the use of refined corn sugar, dextrose, in whole or in part, has been permitted since that date by the U. S. Department of Agriculture without declaration on the label. In common practice,

[1] U. S. Dept. Comm., *Census of Manufacturers*, 1933.

[2] U. S. Dept. Comm., *Trade Promotion Series*, 57, 1928.

$2\frac{1}{2}$ to $2\frac{3}{4}$ parts of fresh milk are reduced to 1 part of condensed milk, while with unsweetened evaporated milk the ratio is usually 2 to $2\frac{1}{2}$ parts of fresh milk to 1 of final product. The sweetened products may be packed in bulk or in tin cans after the removal of water is completed by heating in vacuum pans; while the evaporated milk is usually filled into cans, sealed, and sterilized under steam pressure in continuous rotary sterilizers at 240°F. for 15 minutes, in order to prevent bacterial spoilage. The sweetened condensed milk is usually forewarmed, *i.e.*, heated to above 170°F., previous to the condensation, which is carried out at 130 to 145°F., in order to kill many of the bacteria present and inactivate the enzymes of milk which may cause undesirable chemical and physical changes. Evaporated milk is forewarmed at a temperature of about 200°F. Evaporated milk is homogenized at pressures of 2,000 to 3,000 lb. per inch in order to break up the fat globules and produce a stable suspension previous to sterilization.

It is possible to produce unsweetened, condensed, unsterilized milk which will keep for a time under refrigeration by increasing the ratio to 3:1 or 4:1 for whole milk. This product has its main use in the ice-cream industry.

Concentrated milks are sometimes irradiated with ultraviolet light in order to increase the content of vitamin D which is particularly necessary in the diet of infants and children. This may be done after the milk has been condensed by allowing a thin film to run down the interior of a cylinder whereby it is exposed for a brief period, usually a few seconds, to the rays of special carbon-arc lamps.

TABLE 87.—UNITED STATES EXPORTS AND IMPORTS OF CONCENTRATED MILK

Year	Exports, lb.				Imports, lb.
	Condensed	Evaporated	Dried whole milk	Dried skimmed milk	
1935	4,889,622	32,227,175	1,588,536	1,162,684	602,721
1934	8,202,060	37,963,415	1,689,564	1,430,035	306,451
1933	4,724,582	32,365,212	1,588,890	891,334	1,117,957
1932	11,501,745	39,305,309	1,885,193	1,672,522	1,187,986
1931	19,323,694	55,761,388	12,790,303	1,537,894	1,245,158

Condensed Buttermilk and Skim Milk.—During the World War greater attention was paid in this country to the efficient and economic utilization of creamery wastes. This has resulted in the establishment of many condenseries and drying plants using such former wastes as raw materials for making poultry and livestock feeds, as well as for constit-

uents of foods for human consumption. The latter find use especially in bakeries and ice-cream plants.

One of the materials which was formerly wasted to a considerable extent but is now conserved in large amounts is buttermilk. The annual butter production in the United States is between 1 and 2 billion pounds. For every pound of butter produced there are about 1½ lb. of buttermilk, according to Coe,[1] thus the quantity of buttermilk available is enormous. For 1933 he estimated the production of condensed buttermilk and dried buttermilk each to be greater than 50 million pounds, while in the same year almost 300 million pounds of dried skim milk was produced.

Before buttermilk is condensed, it is usually allowed to ferment for a period of 2 or more days in order to increase the acidity to about 1.5 per cent, calculated as lactic acid, which is desirable for a good product. This may be a spontaneous bacterial fermentation or an accelerated one brought about by adding a starter culture of *B. bulgaricus*.

At the end of the fermentation, during which period the buttermilk has been constantly stirred, the material is heated almost to boiling by the introduction of live steam which continues the agitation. It is then run into a vacuum pan and subjected to heat at reduced pressures for a number of hours until there has been a reduction in volume of approximately 75 per cent.

Skim milk may be condensed in the same manner. It is sometimes subjected to as high a degree of condensation as buttermilk, but the keeping qualities of both products depend on the maintenance of a high final acidity, 4 to 6 per cent lactic acid, which inhibits putrefaction. Some defects in condensed buttermilk may be caused by the use of lime as a neutralizer during the previous butter-manufacturing process in order to reduce the acidity of the cream.

Any products of this nature intended for human consumption must be handled with the same care which all human foods require, and under these circumstances glass-lined tanks and sanitary piping should be used.

Malted Milk.—Malted milk, the predecessor of our numerous modern dried milk products, was first made about 50 years ago in Wisconsin. The popularity of this tasty and nutritious product has extended over a long period and some 7 million gallons of fluid milk are required each year as raw material for its manufacture in this country. Used as a base for beverages, malted milk has wide consumption among adults as well as children and invalids. It is also used as one of the ingredients in numerous soda-fountain drinks where malted milk combines to advantage its fine flavor with excellent nutritive qualities.

[1] See M. R. Coe, *U. S. Dept. Agr. Circ.* 329, 1934, for a more complete discussion of dairy by-products used for feeds and their composition.

As its name implies, malted milk is a combination of malt and milk. The characteristic flavor results from the water extraction of barley malt which has been crushed and mixed in a mash with wheat flour. The water extract of this mash is then thoroughly mixed with milk in definite proportions and dehydrated until the moisture content is reduced to about 3 per cent or less.

The processes involved in malting barley for use in malted milk are similar to those used for other malting purposes and are discussed on page 62. Malt for the production of malted milk requires the abundant development of enzymes, as their ability to hydrolyze starches and proteins is a valuable characteristic. The wheat flour is used in much larger proportions than the prepared ground malt in making the mash and must be subjected to heat treatment in boiling water previous to mixing it with malt, in order to convert the wheat starch to soluble starch. After cooling, the gelatinous paste from the flour is mixed with crushed barley malt and water to form a mash. The mash is heated to accelerate the diastatic and peptonizing action of the enzymes in the malt which hydrolyze the starches and proteins of the flour paste. As the optimum temperature of the diastatic or starch-splitting enzymes is somewhat higher than that for the proteolytic enzymes, the mash is heated to slightly above 40°C. for a sufficient period for the proteolytic enzymes to function. Then the temperature is slowly raised to the temperatures which favor the hydrolysis of starches. The upper limit of temperature required is in the vicinity of 70°C. and the heating is terminated when the hydrolysis of starch is complete. The mash may then be filtered after the gross particles and the hulls have separated by gravity.

The extract of malt and wheat flour thus obtained may be combined with whole milk, also in some instances with very small quantities of salts, such as chlorides, bicarbonates, citrates, or phosphates, before concentrating. The extract and the milk may be partially concentrated separately, then combined, and the dehydration completed.

The first stages of concentration may take place in ordinary vacuum pans, but the final dehydration to the dried form is usually performed with spray driers, drum driers, or vacuum pans equipped with agitators. The product is ordinarily packed in sealed containers as it takes up water readily from the atmosphere if exposed. With the exception of this difficulty, malted milk usually keeps satisfactorily and better than most other dehydrated milk products.

Some special products such as chocolate malted milks are manufactured in relatively small quantities.[1]

[1] For a detailed description of the manufacture of malted milk and other milk products, see O. HUNZIKER, Condensed Milk and Milk Powder, 5th ed., 1935. La Grange, Ill.

Table 88 gives data concerning the composition of several samples of malted milk of different manufacture analyzed by the New Hampshire State Department of Health Laboratories in 1936.

TABLE 88.—MALTED-MILK ANALYSES*

Form	Equivalent price per pound, cts.	Moisture, per cent	Ash, per cent	Albuminoids, (N × 6.38), per cent	Fat, per cent	Starch	Remarks
Package..	114	3.27	4.25	14.92	8.22	None	Passed
Bulk.....	63	3.41	3.98	14.56	7.76	None	Passed
Package..	133	3.48	4.92	12.15	7.47	None	Fat very slightly low
Package..	63	2.93	4.42	11.88	7.43	None	Fat slightly low
Chocolate Package	50	2.94	2.68	8.47	7.58	Small amount†	Misbranded; not "extra-rich"
Package..	114	2.86	3.50	14.47	7.99	None	Passed
Bulk...	50	5.13	3.30	12.40	7.73	None	Moisture in excess of limit
Bulk...	39	5.24	3.35	10.65	9.10	None	Moisture in excess of limit

* From "Health," Bulletin of New Hampshire State Department of Health, February, 1936. (Courtesy of Mr. Charles Howard.)

† Added cocoa.

DEHYDRATED OR DRIED MILK

Another method of preserving milk and milk products such as skim-milk, buttermilk and cream, which has come into wide usage in the past 20 years, is to concentrate them by removing water to the extent that the final dehydrated product is in the form of powder or flakes. The dried or dehydrated milk thus obtained may be kept for considerable periods, provided it is stored or packaged in a manner which prevents access of moisture.

The first product of this nature was malted milk, as described in the previous section. In recent years powdered whole milk has been manufactured in the United States to the extent of more than 10 million pounds annually and in 1933 almost 19 million pounds were produced. The production of dried skim milk has been 15 times as great, and powdered-buttermilk production has now become three times that of powdered whole milk. Cream is also dried but to a lesser extent, the 1933 production being about 4.5 million pounds.

The United States has been the leading producer of such dehydrated products and her annual production has been more than twice that of Switzerland, her nearest competitor. Australia, Netherlands, Canada, and New Zealand are also large manufacturers of dried milks.

There are a number of methods by which milk in its various forms may be dried, either alone or in combination with other materials, as is the case with malted milk. The more commonly used appliances are drum driers, spray driers, or flake-film driers.

The drum driers may be operated at atmospheric pressure or under a partial vacuum. The milk is sometimes concentrated in a vacuum pan before being subjected to the final drying. When whole milk is to be dried, it is first homogenized if it is not condensed. The drying is accomplished by spreading a thin film of the milk on a heated cast-iron rotary cylinder or drum. This film may be spread by an auxiliary cylinder which dips in the milk-supply tank, by means of an overhead supply and the use of two drums rotating in opposite directions, or by means of spray jets. The temperature and rate of rotation of the steam-heated drum, or drums, if two or more are used, are controlled so that the milk is dried in less than a complete revolution, and the thoroughly dried product is scraped off by mechanical knife edges. These scrapers or "doctors" must be very carefully adjusted or the quality of the product will not be uniform, as some of it may go through two cycles and be discolored or damaged in physical character as a result. The use of vacuum-drum-drying equipment generally results in a better quality product as lower temperatures may be used and the solubility of the product is higher. Vacuum equipment is likely to be more expensive, however, and is therefore confined to dried products intended for human consumption.

The spray methods of drying milks utilize preheated milks which are usually concentrated in vacuum pans to facilitate the later process. Homogenizing precedes spraying if the milk contains all its original fat and is not to be concentrated in vacuum pans previous to the main drying operation. The homogenized or partly condensed milk is atomized under pressure, by means of spray jets or centrifugal sprays, into a heated chamber in the form of fine mist. Here it comes in intimate contact with heated air, the air temperature varying in different processes from about 180 to 400°F. In some methods the air is forced into the chamber at high velocity and is pulled out by other mechanical pumps or fans. When the milk spray comes in contact with the hot air in the drying chamber, the water content of the milk is almost instantaneously removed and the dried product drops to the bottom as a powder. The very short period of exposure to high temperatures to which the milk is subjected results in a product much more soluble in water than the usual product from drum driers, unless the spray-dried milk was subjected to severe temperatures, *i.e.*, those of 200°F. or over, during preheating or condensing. It is desirable to cool the finished powder as soon as possible because prolonged high temperatures cause deterioration. Some manufacturers use refrigerated air for this purpose.

In addition to the milk driers discussed previously, the flake-film method involves somewhat different principles. By the use of vacuum pans the milk is concentrated in a ratio of approximately 4:1 and then chilled. The concentrated viscous product is agitated in a special apparatus equipped with a dasher, and heated air is discharged into the

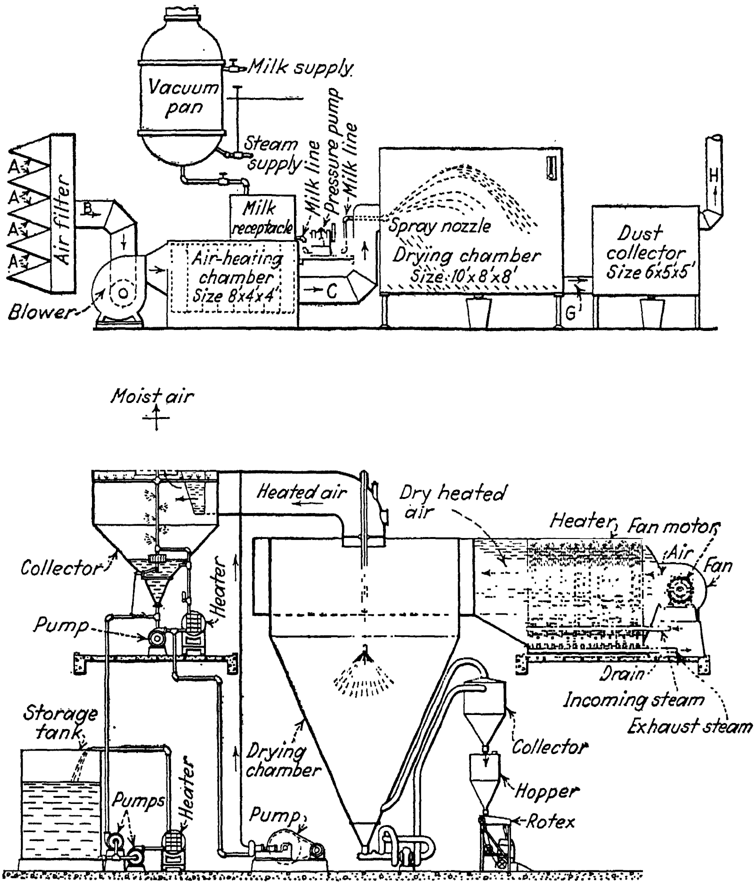


FIG. 43.—Illustrations of milk drying processes by spray methods. (*Taken from Circ.* No. 329 *U. S. Dept. Agr.* 1934.)

mass until it is puffed up to form a light airy material which may be run out on the surface of a wire-mesh belt. The belt is part of an endless conveyor traveling through a heated dehydrating tunnel which dries the milk by the time the end of the tunnel is reached. This method is more applicable to milk products having a low-fat content, such as skim milk, which are not so subject to oxidative changes likely to occur because of prolonged contact of the fats of the milk with warmed air.

Dried Buttermilk and Skim Milk.—In 1933 dried and powdered buttermilk were manufactured to the extent of more than 61 million pounds in the United States, while dried and powdered skim milk were produced to the extent of over 250 million pounds.

There are two general methods of manufacturing dried buttermilk, the roller process and the spray process. The roller process was the one

TABLE 89.—ANALYSES OF SOME MARKET DRIED-MILK PRODUCTS*
Per cent

Dried product	Moisture	Fat	Protein	Ash	Lactose	Lactic acid	Remarks
Skim milk	7.44	0.65	36.75	20.60	3.21	0.23	Roller process. Used for baby food
	5.92	9.12	36.06	7.33	37.98	1.35	Spray process. Sweepings and discolored portion used for feed
	6.45	0.25	31.88	7.80	47.03	1.63	Roller process. Used for baking purposes
	6.33	8.60	31.69	7.18	38.63	1.21	Roller process. Used for feed
	6.54	0.28	33.44	7.55	44.02	1.86	Spray process. Used for food
	7.04	0.36	31.44	7.84	45.83	1.75	Spray process. Floor sweepings after 24 hours' run. Used for feed
	6.87	0.16	32.94	7.78	43.07	2.00	Spray process. Floor sweepings after 24 hours' run. Used for feed
	3.67	0.01	30.69	8.35	49.01	1.91	Spray process. Used for food
	4.60	0.14	34.25	7.91	47.92	1.67	Roller process. Used for food
Whole milk	2.78	25.27	23.94	5.90	31.62	1.30	Roller process. Used for food
Buttermilk	6.49	13.86	33.56	9.35	14.40	8.09	Roller process. Made from semisolid and liquid buttermilk. Used for feed
	8.64	9.29	34.06	12.21	9.00	8.93	Roller process. Used for feed
	8.42	7.96	34.25	14.17	23.90	11.12	Spray process. Cleanings from 24 hours' run. Used for feed
	8.76	5.28	33.56	13.42	7.73	9.54	Spray process. Good grade. Used for feed
	4.65	3.28	32.75	8.53	37.53	4.69	Spray process. Used for feed

* Taken from *U. S. Dept. Agr. Bull.* 329, 1934.

largely used for buttermilk during the earlier days of this growing industry. In this method the buttermilk, which may have been partially condensed previously, is sprayed on the exterior of a steam-heated, slowly revolving roller and the resulting film scraped off by a stationary knife before the roller has made a complete revolution. The product rarely goes higher than 200°F., but its color may be any shade from cream to dark brown. Those of darker color are usually higher in acid content and ash.

Several spray processes are in use for the making of dried skim milk and buttermilk. The higher grade products are used for foods, the others for feeds. One of these processes involves the spraying of the skim milk under high pressure into a drying chamber through which previously heated forced-air currents dry the mist formed thereby at a temperature of about 190°F. The sprayed material is dried almost instantly and drops to the floor, where it is removed by gravity. Air filters and dust collectors are used to clean the air before heating and to catch the milk powder carried out by the air blasts after leaving the drying chamber.

Another method uses an overhead spray in the upper part of a drying chamber shaped like an inverted cone, in which case the dried material drops to the base of the funnel-shaped chamber and is mechanically removed. One spray process utilizes a screw conveyor at the bottom of the heating chamber to remove the dried material.

The reduction in weight resulting from drying skim milk is generally over 90 per cent, so there is a considerable lowering in transportation rates of the finished product if it is to be shipped some distance. The keeping quality of the products is dependent on low moisture content, and storage conditions must be watched carefully if the dried product is not packed in relatively moistureproof containers.

Table 89 shows the analyses of some market dried-milk products examined by Coe (1934) who stated that there is a tendency for even lower moisture contents in manufacture than those given in the table.

Whey, which is rich in lactose or milk sugar, and results from the manufacture of cheese, may also be dried and conserved in large quantities for stock and poultry feeds.

Changes in Powdered Milk during Storage.—All powdered milks are liable to chemical and bacterial changes unless handled properly. The heat treatment to which the milk is subjected during drying is sufficient to kill many of the bacteria present but does not sterilize the product. The drum-dried products are generally lower in bacterial counts than the spray-dried because of the more severe heat treatment. If the powdered milk is carelessly exposed to moisture or air of high humidity, the water content of the milk may be increased to the extent that the bacteria remaining after the drying process will be able to renew their suspended

vital activities and gradually spoil the product. The solubility of milk powders is lowered on storage if the moisture content is high. This is believed to be due to changes which particularly affect the casein. Because of these reasons dried-milk powder is usually packed in watertight containers, using barrels with a special waterproofing coat of sodium silicate or similar agent on the inside. For smaller units, tin cans, glass jars, and moistureproof cartons are used.

Milk powders are also subject to oxidative changes which occur in the milk fat on exposure to air, particularly the unsaturated fats, and marked objectionable tallow-like flavors may result. These reactions may be retarded by storage at low temperatures, by the removal of oxygen, and exclusion of light. Many of the small domestic containers for powdered whole milk and powdered cream are evacuated to remove as much air as possible, and inert gas such as nitrogen may be used to replace the air. This treatment is helpful in lessening the incidence of tallowiness, but it is still desirable to use low storage temperatures as some oxygen is left in the product even after evacuation. The use of a clarifier soon after milking may also be helpful in lessening the incidence of tallowiness.

Milk powders may also become rancid, owing to the enzymic hydrolysis of the milk fats by lipases from microorganisms. These enzymes may be inactivated by heat. Spray-dried milk is much more subject to deleterious changes of this nature than drum-dried powders which are more severely heated. More careful control of the heat treatment is therefore indicated. As the quantity of lipases or lipolytic enzymes is dependent on the concentration in the original milk and is correlated with the microorganisms in such milk and their activities, rigid standards on the bacterial quality of raw milk should be maintained.

The optimum conditions of temperature for storage of dried milks lies between 30 and 45°F. Higher temperatures are likely to accentuate rancidity and tallowiness, and other undesirable storage odors are likely to occur at lower refrigeration levels. Under the latter conditions mustiness or moldy and stale odors or tastes may occur on extended storage.

From a consideration of these factors it is apparent that the storage and packing of powdered milk present numerous difficulties, and in the past these difficulties have limited the market for those dried-milk products containing as much fat as dried whole milk or cream. Great improvements have been made since the start of this industry and within the past decade the powdered milks have become better known and have received general acceptance by the householder as well as by the medical profession. Other improvements eliminating the storage changes of taste, odor, and solubility would cause a tremendous impetus to this industry. The day may not be far distant when the inefficient expensive

daily delivery of fluid milk will be substituted in large part by the use of much greater quantities of dried whole milk in the home.

LACTOSE

Lactose, or milk sugar, is found in the milk of practically all mammals and has been recognized over 300 years. The lactose content of milks of different mammals varies from approximately 2 to 8 per cent. Cow's milk averages approximately 4.8 per cent, roughly one-third of the total solids. The manner in which lactose is produced in the body is still undetermined, but it seems likely that it may be the result of the condensation in the mammary gland of the two molecules of glucose with the internal rearrangement of one of the molecules to galactose.

There are three forms in which lactose occurs. The alpha (α) lactose hydrate, $C_{12}H_{22}O_{11}.H_2O$, is the common form produced commercially. This is less soluble and less sweet than the beta (β) lactose anhydride. The third form is the alpha lactose anhydride. The first two are of more significance as items of commerce.

Lactose is used for dietary, therapeutic, and medicinal purposes. Of the sugars normally in the diet it alone may reach the small intestine without being broken down, if consumed in sufficient quantities, and thus offers a food for fermentive bacterial types of the intestinal flora, increasing their action and checking to some degree the action of the putrefactive types and in this way controlling autointoxication. The ease with which it can be digested makes it useful in diets for invalids and for modifying milk for infants. As a diluent and sweetener it is used extensively in the production of such pharmaceuticals as pills, tablets, etc. The confectionery trade utilizes limited quantities in certain candies, and in certain liquors it is desired since by crystallization of the sugar a frosty appearance is given to the bottles.

Until 1880 the production of commercial lactose was confined largely to Switzerland. It was subsequently produced in other European countries, the United States, and at a later date in Australia. The United States production has amounted in recent years to 5 to 12 million pounds. The sources of milk sugar are cheese whey, rennet-casein whey and acid-casein whey. Of these the last is most important as the result of investigations by the U. S. Department of Agriculture on casein production. These investigations have shown that a more uniform casein can be produced by the acid-casein method with the result that today this process leads all others.

The manufacture of lactose from acid-casein whey is essentially as follows. The whey is a by-product in the production of casein which is obtained by precipitation from skim milk by the addition of dilute hydrochloric acid. After removal of the precipitated proteins, the

resulting whey contains on the average 93 per cent water and 5 per cent lactose, with the ash, residual proteins, and fat comprising the balance. This whey is heated by direct steam in large iron tanks and gradually neutralized to pH 6.2 by the addition of milk of lime. Heating is continued nearly to the boiling point. By this time much of the remaining proteins has been coagulated and has risen to the top. The clear whey is drawn from the bottom of the tanks into a vacuum pan and concentrated to 20°Bé., the resulting sirup being passed through a filter press. The coagulated proteins from the first heating are also filtered and the filtrate added to the filtered sirup. Further concentration in vacuum pans is now effected. During the concentration the sirup is seeded with lactose crystals of suitable size to insure proper crystallization. As the concentration proceeds, the process is slowed down so that large crystals may be formed. When concentrated to about 40°Bé., the sirup is run into crystallization vats, and agitated while it cools slowly. The crystallized material is later centrifuged and the crystals washed with cold water while still in the centrifuge, followed by drying on trays in hot-air tunnels. The yield is about 3.75 lb. of sugar to 100 lb. of whey and the sugar contains from 80 to 90 per cent lactose. The mother liquor from the centrifuge may be recrystallized or dried and used in stock feed.

This sugar is still impure and is usually subjected to a refining by redissolving in water to make a sirup of from 13 to 15°Bé. Bone black and acetic acid are added and the mixture heated to boiling when a small amount of magnesium sulphate is added. Boiling is continued until the sirup is decolorized and a flocculent precipitate of protein and phosphate occurs. The sirup is then passed through a filter press to free it from the precipitate which may be washed and treated with sulphuric acid to yield a fertilizer. The filtrate is then concentrated and crystallized. Drying of the crystals is accomplished in rotating air dryers following which the sugar is ground to a certain fineness. The yield of refined lactose is only about 2.5 per cent as there are losses owing to the action of microorganisms and chemical hydrolysis, as well as inefficiencies in the various processes employed.

One factor that has had a retarding effect upon the utilization of lactose is that the lactose of commerce is the low soluble and less sweet alpha hydrate. Recently much work has been done on the conversion of the hydrate to the beta anhydride form. The hydrate is the form normally produced when crystallization is accomplished below 93°F., the beta form occurring at higher temperatures. A process has been devised whereby commercial lactose is dissolved in water at the rate of 60 lb. of lactose to 40 lb. of water and is held at 92°C. for ½ hour. This results in a solution containing equal parts of the alpha and beta forms which when dried on a rotating-drum dryer yields an almost pure beta sugar. This powder

must be packaged in moistureproof containers to insure a water content of not more than 1 per cent, or a change to the hydrate form will occur.

See HUNZIKER, O. F., Condensed Milk and Milk Powder, 1935.
WHITTIER, E. O., *Chem. Rev.*, **2**, 85, 1925–1926.
Report of the Chief of the Bureau of Dairy Industry, *U. S. Dept. Agr.*, 1930.

CREAM

Cream is the more concentrated source of milk fat from whole milk and for this reason is more desirable for certain food uses in which richness and flavor are required and dilution is objectionable. As an article of commerce it attains wide consumption for table and culinary purposes in the metropolitan areas, as is indicated by the receipts in New York City in 1932 of 18 million gallons of fresh cream, a volume equivalent to some 100 million gallons of whole milk. In the same year 339 million gallons of whole milk were received in New York. The most important use of cream, however, is as a raw material for the manufacture of butter. Many thousand gallons of cream are also utilized in the making of ice cream. It also attains a considerable use in homes for cooking purposes and for "table" or "coffee" cream.

Previous to 1930, cream was imported into the United States from Canada to a considerable extent, but such imports were reduced by later tariff regulations. In 1932 about 118,000 gallons were imported.

A considerable part of the cream separated from milk is converted into butter in the great dairy regions. That which is intended for direct domestic use or by hotels and restaurants at great distances from the place of production is generally separated at the dairy or country receiving station, because it is more advantageous to make shipments of the less bulky cream and thereby cut down the costs of transportation involved in shipping milk. Cream kept under proper conditions of refrigeration may be stored for longer periods than milk. It may also be frozen in periods of surplus and used months later in times of need.

In accordance with Federal definition, "Cream is that portion of milk, rich in butter fat, which rises to the surface of milk on standing, or is separated from it by centrifugal force. It contains not less than 18 per cent of milk fat and not more than 0.2 per cent of acid-reacting substances, calculated in terms of lactic acid."

Massachusetts Standards for Cream.—The Massachusetts legal standard for cream or ungraded cream shall be cream which, upon analysis, is shown to contain not less than sixteen per cent of milk fat. The Massachusetts standards for the grades to be known as light cream, medium cream, heavy cream, and extra heavy cream shall be cream which, upon analysis, is shown to contain not less than

sixteen, twenty-five, thirty-four, and thirty-eight per cent, respectively, of milk fat.[1]

NOTE: In most states the minimum legal fat standard for cream is 18 per cent.

The separation may be carried out merely by allowing the milk to stand for a number of hours during which time the fat globules tend to rise because of their lower specific gravity. The same result may be accomplished more efficiently in a few minutes by means of a cream separator, using centrifugal force, and by proper adjustment of the apparatus previous to usage, the cream may be obtained of a desired fat content.

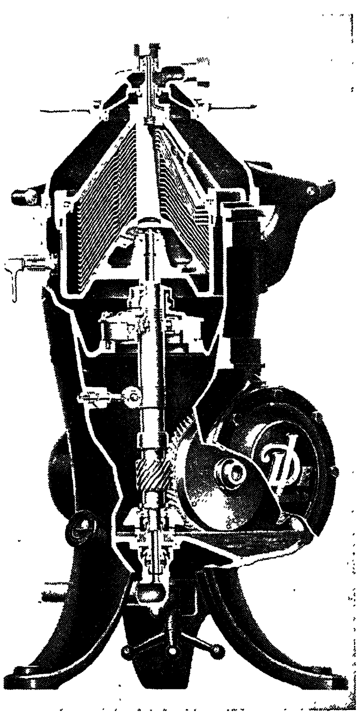


FIG. 44.—De Laval airtight separator. (*Courtesy De Laval Separator Company.*)

A recent development in cream separators enables the use of a tightly sealed system which eliminates some of the undesirable features of those open to air. The cream and milk are less subject to oxidative changes and may be delivered free from foam. With the airtight separator system it is also possible to elevate the cream and skim milk to higher levels without the subsequent use of pumps which are likely to cause injuries from a physical standpoint. It is also possible to change the adjustment of fat content of the cream while the separator is in operation.

Composition of Milk Fat.—The fatty portion of cream is composed of complex glycerides, among which are normally found: butyric, caproic, caprylic, capric, lauric, myristic, palmitic, stearic, and oleic acid compounds, the first four of which are soluble. The fat owes its flavor in large part to the glycerides of the lower fatty acids, butyric, caproic, caprylic, capric, lauric, and myristic, the first four of which are also volatile. Glycerides of the volatile acids comprise about 17 per cent of the total. Butyric acid, one of the most important in respect to flavor, and also to rancidity, is subject to variation in amount according to the feed of the animal and the period of lactation. The longer the period after parturition, the lower the butyrin becomes. Corn silage, beets, molasses and wheat gluten in the diet of the cow are said to increase

[1] Massachusetts General Laws, Chap. 94, Sec. 12.

the amount of combined butyric acid, while cottonseed meal has the opposite effect.

The hardness or softness of milk fat, which is dependent on the melting point of the constituent fats, determines the temperature at which the cream should be churned if used for butter. A soft butter or one with a low melting point requires a lower temperature for churning. The softness of such fat is largely due to the presence of oleic acid and the percentage of oleic acid is increased by the feeding of green grass or feeds rich in vegetable oils such as flaxseed, linseed, cottonseed, and soybean meals. The amount of oleic acid also increases with the period of lactation of the cows. Underfeeding causes a decrease in the amount of volatile acids, with a resulting increase of oleic acid.

Holstein, Shorthorn, and Ayrshire breeds produce a butter fat higher in olein than in Jerseys or Guernseys. The latter two breeds give milk containing more of the volatile acids. These factors indicate that Jersey and Guernsey cream can be satisfactorily churned at a lower temperature than the others.

Fat is found in milk in the form of an emulsion. The globules are very small in size being only a few microns in diameter. Each globule is believed to be surrounded with a layer of proteins (nucleosides) and lecithin, which maintain their position in respect to the globule by surface attraction or adsorption.[1] The film about the globule tends to produce a stable emulsion.

Cream delivered to the consumer in the glass half-pint bottles used in metropolitan areas often presents just under the cap of the bottle a "cream plug" caused by the incidental churning effects likely in transportation. This may result in a characteristic "oiling off" if used in hot coffee, which may be avoided if the cream is subjected to homogenization in the dairy. In some states this practice is illegal, however.

Homogenization, or the use of a process whereby milk or cream may be forced through a minute aperture or valve capable of extremely accurate size adjustment under high pressures, enables the size of the fat globules to be changed and thereby alters the physical character of the fluid used. Such action increases the surface area of the globules enormously, enables protein adsorption at the fat-liquid interface, and results in a more stable suspension which tends to retard coalescence of the fat particles. The term viscolization is synonymous with homogenization. The temperature at which homogenization of cream is carried out is important, and depends largely on the subsequent heat treatment to be utilized. This process is generally carried out at temperatures above those of pasteurization.

[1] ECKLES, COMBS, and MACY, Milk and Milk Products, McGraw-Hill Book Company, Inc., 1936.

Cream may be pasteurized in a manner similar to that used for milk. Such treatment eliminates the hazards due to bacterial pathogens and enhances the keeping qualities of the product. The "body" or viscosity of cream is an important factor and by heat treatment at temperatures of 83 to 86°F. it is possible to improve the character of cream in this respect.

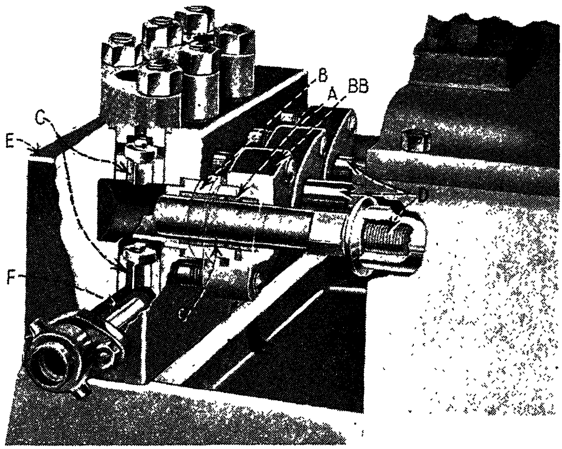


FIG. 45.—Construction of Cherry-Burrell sanitary viscolizer. (*Courtesy Cherry-Burrell Corporation.*)

A, removable single-seal sanitary packing; *B*, removable sanitary packing box; *BB*, removable sanitary packing gland; *C*, interchangeable stainless-steel suction and discharge valves; *D*, removable hardened stainless-steel plunger rods; *E*, stainless-steel cylinder block; *F*, smooth passages; *G*, removable bushings for guided stroke.

Frozen Cream.—Large volumes of cream destined for use in other dairy products may be kept for considerable periods of time by freezing and storing in the frozen condition. This is usually done during periods of high production when the costs of cream are lower. Such products must be of good flavor and handled so as to maintain high sanitary quality, but they do not necessarily require quite the same care in treatment from the standpoint of texture, body, and appearance.

Containers formerly used for the storage of frozen cream included ordinary milk and cream cans or even butter tubs. For sanitary reasons, large tin cans with flush-soldered seams have come into use for this purpose within the past few years. In such containers of 5- or 6-gal. capacity, holding 45 to 50 lb. of cream, the product may be frozen at very low temperatures, *i.e.*, −25°F., and later stored at temperatures of −7 to 10°F. According to Page,[1] cream keeps better the higher the fat content, but precautions should be taken to use only cream of high quality which has a low acidity and low bacterial counts. To eliminate oxidative

[1] PAGE, *Food Ind.*, **3**, 207, 1931.

changes as far as possible, the cans should be well filled, and foaming of the cream during filling prevented, thereby minimizing the inclusion of air.

BUTTER

Butter is our most important dairy product other than fluid milk, and the United States is the leading butter-producing country, with a production of about 2 billion pounds a year. Other large producing countries are Russia, Denmark, Australia, Canada, New Zealand, and Belgium.

Denmark, New Zealand, and Australia are the foremost exporters of butter, although others of importance are the Netherlands, Russia, Argentina, Irish Free State, Sweden, Finland, and Poland.

The greatest importing country of butter is the United Kingdom, followed by Germany, Belgium, France, and Switzerland.

The per capita consumption of butter for the United States in 1931 was 18 lb., which is greater than that of Germany, Sweden, Great Britain, and most other European countries, with the exception of Netherlands. Australia, Canada, and New Zealand, which are all important butter-producing countries, appear to use much more butter in their diet than is the case in the United States, and the per capita consumption in New Zealand is just twice that in the United States.

The production of butter substitutes consisting in part of milk products but largely of other fats of vegetable and animal origin, has increased in recent years. The average consumption of these products in the United States has been about 2 lb. per capita for the past decade.

Creamery butter, or that produced in creameries or factories, as contrasted with that made on farms, constituted about 75 per cent of all butter produced in the United States in 1935, whereas in 1920 only about 50 per cent was factory-made, and 20 years previous to that time over 60 per cent of the butter was made on farms. This definite trend toward factory production under more carefully controlled conditions will doubtless continue to be more marked as time goes on. Creamery butter is made in every state in the United States. The three states producing the largest quantities are Minnesota, Iowa, and Wisconsin, which together contribute more than 40 per cent of the total production. Other important states are Nebraska, Ohio, Michigan, California, Kansas, Illinois, and Indiana.

There is considerable seasonal variation in butter production, with the high peak usually in June. During May, June, July, and August over 40 per cent of the annual production of creamery butter is manufactured, with the lowest seasonal production during December, January, and February.

The following definition of butter is that accepted by the U. S. Department of Agriculture: "Butter is the food product usually known as butter, and which is made exclusively from milk or cream, or both, with or without common salt, and with or without additional coloring matter, and contains not less than 80 per cent by weight of milk fat, all tolerances having been allowed for."

TABLE 90.—UNITED STATES DAIRY PRODUCTS—FACTORY-PRODUCED (1931)
(1,000 lb.)

Creamery butter	1,667,452
American cheese (whole milk)	374,648
Evaporated milk	1,428,993
Dried or powder buttermilk	50,535
Powdered whole milk	12,627
Powdered skim milk	261,938
Dried casein	35,335
Malted milk	19,197
Milk sugar (crude)	9,562
Ice cream, gallons	208,239

The production of fine butter starts at the dairy and requires the use of milk, obtained from healthy herds, which has been carefully handled and refrigerated. Abnormal odors and flavors in the milk or cream must be eliminated as far as possible because they may be absorbed easily by the fat and therefore influence the quality of the butter to a considerable extent.

The cream may be removed from the milk either by gravity separation and skimming or by means of a mechanical separator or centrifuge. The latter method is now almost universal. The use of a properly adjusted centrifugal separator is much more efficient than the slower gravity method, as the cream removal is more complete and it is usually accomplished while the milk is still warm from milking; thus a saving of time is effected. If the milk is allowed to become cool before separation, it is desirable to warm it to about 70°F. to prevent the solidified fats from adhering to the metal and clogging the machine.

The older method has a further disadvantage, for during the rising of the cream, which takes a number of hours, the possibility of odor absorption and contamination by dust and dirt from the environment is also increased.

Butter may be churned from four classes of cream: raw and ripened, raw and sweet, pasteurized and ripened, pasteurized and sweet. Cream may be allowed to ripen spontaneously or become partially soured through the growth of microorganisms already present in the milk, or a "starter" may be added to hasten the process. A starter is a culture of bacteria having special biochemical characteristics and activities which result in better regulated and more uniform souring and flavor production.

Since butter is judged by the user according to its taste, extreme care must be exercised to secure a product of fine flavor. The absorption of the by-products of bacterial fermentation by the fat in butter brings about most of the flavors. In a spontaneously ripened cream there is nothing to prevent the possibility of undesirable types of bacteria from predominating, in which case the result may be undesirable flavors in the butter. The use of proper starters containing vast numbers of bacteria of a favorable type tends to obviate this difficulty.

Two types of bacteria are quite commonly chosen for this purpose because of the very desirable flavor and aroma imparted to butter by them when used together. The first of these is a type of lactic acid bacteria, generally *Streptococcus lactis,* which ferments lactose or milk sugar with the formation of lactic acid. At present a lactic acid content of about 0.4 per cent in cream is deemed most desirable for churning purposes, although formerly a content of 0.7 per cent was considered more satisfactory. The second type of bacteria incorporated in butter starters has the ability to attack the citric acid present in milk in small quantities with the formation of volatile acids.[1,2] These associated organisms, such as *S. citrovorus* and *S. paracitrovorus* appear to have the more important role in the development of flavor and aroma.

The chemical constituents which have been found of particular importance in this respect are acetylmethylcarbinol and diacetyl, which are developed during the latter part of the ripening process, and appear to be developed from the citric acid or citrates normally present in milk.[3]

Diacetyl may be produced by the oxidation of acetylmethylcarbinol and the former compound may be found in high-quality butter to the extent of a few ten-thousandths of one per cent which is sufficient to cause the desired aroma that characterizes fine butter.

If cream is allowed to stand at room temperature, it will generally be of best quality for butter making during the first 4 days, with an optimum at 3 days, and of relatively poor quality after about 7 days. This, according to Parker and Whittaker,[4] is because of depletion of the citric acid content, and the development of bacteria which are more likely to produce off-flavors, owing to their proteolytic and lipolytic action.

Hammer and his coworkers[5] have recently reported that citric acid-fermenting organisms may reduce acetylmethylcarbinol or diacetyl to

[1] van Niel, Kluyver, and Derx, *Biochem. w.*, **210,** 234–251, 1929.

[2] For a detailed description of butter starters see Dairy Bacteriology by B. W. Hammer, John Wiley & Sons, New York, 1928.

[3] Michaelian, Farmer, and Hammer, *Iowa State Coll. Agr. Res. Bull.* 155, January, 1933.

[4] Parker and Whittaker, *Am. Creamery and Poultry Product Rev.*, Dec. 12, 1934.

[5] Hammer, Sathly, Werkman, and Michaelian, *Iowa State Coll. Agr. Res. Bull.* 191, Dec. 1935.

2, 3-butylene glycol under certain conditions, a change which is undesirable as far as butter flavors are concerned. A low pH and low temperatures tend to delay this reduction as they are unfavorable to the organisms. The use of sodium chloride in salted butter and the low holding temperatures of butter are also suggested as factors in preventing this disappearance.

Commercial starters may be obtained in both the liquid and dry state. In order to make a starter, a quart or so of milk is pasteurized at 180°F. for 30 minutes. It is cooled to approximately 70°F. or room temperature and inoculated from the commercial starter, which is a culture of the types of bacteria desired. The milk is incubated for 12 to 18 hours, or until the correct acidity is obtained. The starter thus produced is called the "mother starter." Large batches of pasteurized whole milk or skim milk are cooled to 70°F., then inoculated with the quart-size mother starter. (Diluted condensed skim milk or milk powder solution may also be used in which to grow the cultures.) It is from this batch that inoculants for the cream which is to be ripened are taken, and as a rule from 5 to 10 per cent of the cream is composed of the starter. If the starter is not to be used immediately, it is cooled to below 50°F. until such time as it is to be used.

Butter made from spontaneously ripened cream is often too high in acidity and does not keep well. The acidity of the ripened cream may be diminished by neutralizing with carbonates which are sprayed into the cream until the desired reaction is reached. Too much alkali, however, is apt to cause a limelike flavor in the butter. Generally 12 to 18 hours at the temperature noted above is sufficient to ripen the cream.

Butter made from raw sweet cream is difficult to churn and considerable fat is lost in the buttermilk. That made from pasteurized but unripened cream has excellent keeping qualities. Most butter, however, is produced from ripened, pasteurized cream. Pasteurization kills most of the microorganisms present, including any pathogenic bacteria likely to be present in milk, and also inactivates some of the lipases and proteolytic enzymes. It also is of benefit because it permits and may favor the development of surviving lactic acid bacteria.

After the cream has been ripened and is ready for churning, the temperature is raised to that necessary for churning and held there for 2 or 3 hours. It is then strained through a fine wire strainer to remove any dirt or small particles of curd.

The cream when put into the churns should be at least 30 per cent fat because the agglomeration is more rapid when the fat globules are closer together as in heavy cream, but if the cream has too high a fat content, some of it is likely to adhere to the side of the churn and form masses which make churning difficult. The usual practice is to have the fat

content between 30 and 33 per cent. The churn should not be filled over half full, in order to receive the proper agitation. On the other hand, if insufficient amounts of cream are used, a part of it tends to stick to the sides of the churn and prevents proper churning. In the summer the usual temperature of churning is between 52 and 58°F., but in the winter the temperatures are sometimes raised to as high as 65°F.

Since butter is formed from cream by agitation and the concussion and coalescence of the fat globules, it is essential that the churn should cause the cream to rise and fall rather than merely to flow around. If the speed of the churn is too great, the cream remains practically stationary, while too slow a velocity favors a flowing motion of the cream.

Factors Relating to Churning Operations.—Factors which affect the churning time of cream from individual cows include the size of the fat globules in the cream, the stage of lactation, and the breed. When using mixed cream from many dairies, the season of the year, the feed of the animals, the acidity of the cream, viscosity, and the amount of bacterial contamination of the cream are important factors.

The size of the fat globules is dependent in part on the breed of the producing cow. Jerseys and Guernseys produce comparatively large-sized globules while those of the Holsteins are considerably smaller. The larger the fat globules the shorter the churning time is likely to be. The more advanced the period of lactation, the smaller the size the fat globules become in the milk of an individual cow. In winter the cream takes longer to churn unless the temperature is raised sufficiently because once the cream is chilled, the harder it is to churn. Animals fed on cottonseed meal or lacking succulent feed, such as ensilage or beets, are said to produce milk with globules of fat which are harder and more difficult to churn.[1] Very small-sized herds are more likely to produce cream of less desirable qualities, for there is opportunity for more variation owing to the milk of some one cow which may produce poor butter-making cream. In mixed cream from many herds these idiosyncrasies are better balanced.

The fat globules of soured or acid cream cohere more easily than those of sweet cream, hence the advantage of ripened cream with optimum acidity. Viscosity, which retards coalescence, is reduced by acidity. Cream which is heavily contaminated with the bacteria causing gassy fermentation may froth and foam instead of churning, although this happens but rarely.

Churning Operations.—The churn is usually started at the rate of about one revolution per second for a few turns. It is then stopped to allow the escape of carbon dioxide or other occluded gas, although some churns are so designed that the gas may escape during the process without

[1] Judkins, H. F., Principles of Dairying, 1925.

stopping. During churning there is first an incorporation of air and a swelling. Later, owing to the concussions, the fat globules adhere to each other and finally form lumps the size of wheat or corn kernels which gradually coalesce. When globules of this size and upward appear and the buttermilk contains practically no fat, which is evidenced by its thin, bluish watery appearance, the churn is stopped. From 30 to 45 minutes is usually required for the process of churning.

The buttermilk is separated from the butter by draining. Clean, cool water is added to replace the buttermilk and the churn given a few revolutions, after which the water is drained off. This procedure is generally repeated once and is for the purpose of removing nonfatty materials. This washing may also remove to some extent undesirable flavors, and at the same time helps to harden the butter, as the temperature of the wash water is usually between 55 and 60°F. It is essential that the wash water be of high sanitary quality, otherwise bacteria of unfavorable types may infect and reduce keeping qualities of the butter.

Salting.—Salt (NaCl) is added to butter to improve the flavor and to enhance the keeping qualities. It may be mixed with the butter in the churn in the form of a saturated brine, in which case there is sufficient salt retained by this treatment to give a salt content of 1 to 2 per cent. The more customary methods are to sprinkle the salt over the butter in the churn or to add and work in the salt after the butter is removed from the churn.

As a rule, most of the salted butter on the market has a salt content of 2.5 to 3.5 per cent. Since not over 16 per cent moisture is allowed in butter, this would correspond to a brine concentration of over 15.6 per cent salt, which is a concentration sufficient to inhibit many microorganisms.

The salt used in butter should be as free from microorganisms as possible and should contain minimum quantities of magnesium and calcium salts. Magnesium imparts a bitter flavor to butter.

The Working of Butter.—Butter is worked to distribute the salt evenly through the mass, to unite the fat globules as closely as possible, and to expel the excess buttermilk. The best results are obtained when the temperature of the butter and the temperature of the room in which it is worked are between 50 and 60°F. A higher temperature tends to produce a greasy butter and the same result may be obtained by overworking it. It is essential that the final product should not have too high a moisture content, so moisture tests are frequently carried out at this time. If it is found that the moisture is still too high, the working is continued and if there is too low a moisture content, a small amount of water may be added. The body of well-worked butter is firm, compact, and of a waxy nature. The final product should be neither oily nor too dry, flecked, streaked, cloudy, or mottled. Upon breaking it should

present a rough fracture, since this is indicative of good grain and richness in quality. If the salt is unevenly distributed, the product is likely to be mottled and gritty in some portions.

Packing and Storage of Butter.—Butter may be packed directly for market or it may be stored temporarily in new tubs or wooden containers. If it is packed in wood, the tubs or containers should be free from molds, decay, resin, or other odorous substances, and rigidly clean. The use of clear spruce or white-ash wood is said to be preferable for this purpose. Wooden containers should be washed in hot alkaline solutions and then soaked for several hours to eliminate molds. Frequently they are subsequently steamed and paraffined. A parchment lining is put in before the tubs are filled with butter to prevent the direct contact of the butter with the wood where it might absorb odors or come in contact with mold spores.

Chill room temperatures are sufficient for the temporary storage of butter, but continued storage requires a temperature of -6 to $-10°$F. and a comparatively dry atmosphere. The action of microorganisms, particularly molds, is favored by abundant moisture, air, and warmth. The same factors accelerate enzymatic and chemical agencies, hence it is essential to impose conditions which will retard these actions and inhibit them as far as possible. It is practically impossible entirely to prevent changes from taking place, but the better the storage conditions the more nearly perfect the butter will remain.

Off-flavors in Butter.—Butter is subject to off-flavors of many descriptions. Having a rather delicate flavor itself and being composed largely of fats which readily absorb odors, the possibility of acquiring foreign odors requires special attention. Milk may acquire flavors from the feed of the cow, from the barn, or from other sources, but such milk should not be used for butter making. The fat may pick up odors from other foods in the cold-storage rooms if other foods are stored along with butter. Domestic refrigerators and store refrigerators are much more likely to cause trouble in this respect, as large butter-storage rooms are never permitted to handle other foods for this reason.

Butter may have cooked flavors owing to pasteurization at too high temperature. If the cream has been previously neutralized, some flavor from the alkali may be noticeable. Yeasty flavors are possible owing to the Torulae which grow well in milk products and ferment lactose, but this growth occurs mostly in cream not properly handled. Moldy flavors are sometimes noted but reflect evidence of poor sanitary conditions in the handling of cream in either storage or plant equipment.[1] Metallic flavors or aromas may be present in butter but not all such off-flavors are

[1] MACY, Some of the Factors Influencing the Growth of Molds in Butter. *Univ. of Minnesota Tech. Bull.* 64, 1929.

seemingly due to contact with metals. Evidence has been presented by Baker and Hammer[1] that such flavors may be due to certain types of bacteria present in butter cultures and may develop more markedly at low temperatures. That metal salts may be the cause of certain metallic tastes is indicated by the work of Ruehle.[2]

Tallowy flavors may occur in butter and are apparently associated with chemical actions on the fat which are of an oxidative nature. High temperatures and the presence of catalysts such as metals may accelerate such flavors. The condition may be observed in sterile fats, which suggests that microorganisms are not always the responsible agents.

The rancid flavors which sometimes occur in butter are difficult of individual description but resemble butyric acid odors. Certain of these are probably due to bacterial activity and may be accelerated by high temperature. Some of these changes may be due to lipolytic or fat-splitting enzymes. With good raw materials and proper manufacture these flavors are not likely to be found commonly in butter.

An off-flavor which resembles fish or fishiness has been the subject of numerous investigations. It has been ascribed to bacteria by some investigators, but its origin is believed by others to be chemical in nature. The latter consider it probably due to the decomposition of lecithin with the subsequent development of trimethylamine.

Renovated Butter.—Renovated butter is a product made from butter which has been melted, the fat clarified, aerated, and milk, skim milk, or fresh cream added previous to being again churned. Butter is renovated only if it is of low grade or rancid. To renovate butter, it is usually melted to a temperature of about 120°F., and placed in a settling tank. The curd, water, and other impurities settle out and are drawn off, after which these materials are centrifuged to recover any fat which may have escaped with them. The fat is aerated by passing through it a stream of warm, clean air which assists in removing odors. The aerated fat is then pasteurized at 160°F., cooled, mixed with fresh cream, milk, or skim milk, and inoculated with a large portion of starter, after which it is allowed to ripen. After the ripening process, which is for the purpose of gaining favorable flavors and odors, the process is the same as for the manufacture of ordinary butter. The United States production of renovated butter in 1932 was 1,124,000 lb.

Larded butter is the uniform product obtained from the mixing and reworking of odd or miscellaneous lots of butter.

Whey butter is that made from the milk fat obtained from the whey which results from the fabrication of cheese. Whey contains 1 per cent

[1] Baker and Hammer, *Proc. Iowa Acad. Sci.*, **32**, 55, 1925.
[2] Ruehle, *Mich. State Coll. Tech. Bull.* 102, 1930.

or less of milk fat. In 1930, over $2\frac{1}{2}$ million pounds of whey butter were made in this country.

TABLE 91.—PER CAPITA ANNUAL CONSUMPTION OF DAIRY PRODUCTS IN THE UNITED STATES, 1926–1932*

Year	Milk equivalent, all products, gal.	Milk used in cities and villages,** gal.	Butter,† lb.	Cheese,‡ lb.	Condensed milk, lb.	Evaporated milk, lb.
1926	94.9	39.3	17.76	4.36	2.75	11.56
1927	94.7	39.6	17.49	4.14	2.60	11.59
1928	94.4	39.8	17.12	4.11	2.56	12.50
1929	94.5	40.8	17.29	4.62	2.75	13.83
1930	95.0	40.6	17.30	4.71	2.66	13.68
1931	96.9	40.0	18.00	4.49	2.29	13.70
1932	95.5	40.0	18.14	4.39	1.80	14.41

* U. S. Bureau of Agricultural Economics.

** Milk and the milk equivalent of cream consumed per capita by that part of the population not on rural farms. These estimates include some milk and cream used in such products as ice cream.

† Includes both farm and factory butter. These estimates include some butter used in other products such as ice cream.

‡ Includes all kinds of cheese except cottage, pot, and bakers'.

MARGARINE

The manufacture of margarine has a definite place in the food industries of today, although it is an industry far younger than the making of butter, the dairy product which it replaces in the diet of some people. While there is much prejudice against margarines by certain factions, the products are generally made under most strict supervision and from a sanitary standpoint leave little opportunity for criticism.

Both animal and vegetable fats and oils may be used in the manufacture of margarine. When animal products are used, they usually come from animals which have passed government inspection. The vegetable oils are subjected to careful refining operations to remove even traces of natural flavors, and hydrogenated to present the necessary physical characteristics. Coconut oil is especially adapted for this use.[1] These precautions are necessary because margarine fats should be neutral in character and have as little flavor or odor as possible.

Margarines are manufactured with the object of incorporating in these fats of other origin flavors identical with those of butter. It is necessary to use milk in order to accomplish this objective. The butter flavors are developed only through the agency of bacterial fermentations in milk or cream previous to the churning process. The necessity of having the

[1] VAHLTEICH, H. W., *Food Ind.*, **1**, 436, 1929.

right types of bacteria in order to get optimum results is of paramount importance and is brought about by the use of pure cultures which have been selected as having this ability.

Pasteurized milk is inoculated with a desirable pure culture of bacteria, such as organisms of the *B. acidus lacticus* group, and the milk incubated at optimum temperature for the bacterial development of acidity and flavor. When this stage has been attained the milk is introduced into a churn, agitated and the fat added, or the milk may be added to the fat in the churn. The intimate mixing of fat and milk, which may also be accomplished by means of a homogenizer, enables the fat to absorb the

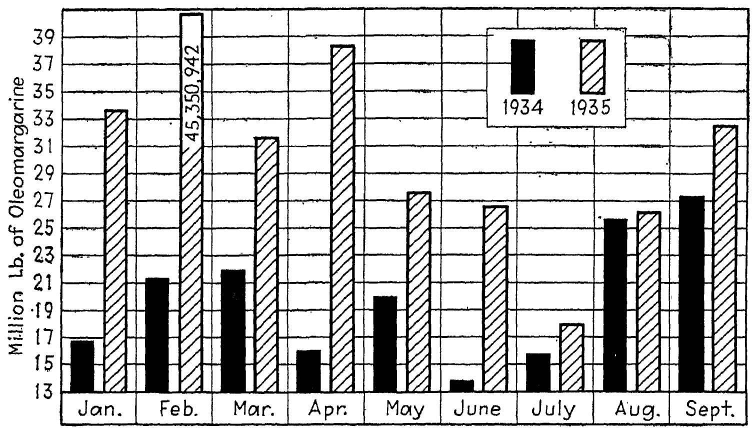


FIG. 46.—The above chart indicates a great increase in oleomargarine consumption in 1935 over that of 1934. There was a 24 per cent increase in the 1933 consumption of butter substitutes over 1932. These products are now consumed to the extent approximating 15 per cent of the United States butter production, according to the *American Agriculturalist*. (*From American Agriculturalist, December* 21, 1935.)

delicate flavoring compounds developed by bacteria in the milk and gives the margarine the desired flavors.

The emulsion thus formed is subsequently chilled or "crystallized" by contact with cold water and conveyed in trucks to storage rooms. Instead of the ice-water treatment the emulsion may be run on the surface of a refrigerated revolving drum and scraped off within a single revolution of the cylinder.

The same or even greater sanitary care in handling is required for margarine as for dairy products such as butter. Some of the better factories are air-conditioned to eliminate bacterial and mold infections which may lower the quality of the product. The equipment requires the same scrupulous attention that all high-class creameries receive today.

After a number of hours' conditioning, the material is worked to incorporate salt and remove water, packaged, and ready for shipment. Some-

times coloring is added previous to packing, although the color may be packed in a separate capsule.

ICE CREAM

Ice cream has become a most popular food product. Once esteemed as a luxury available only in the summer season, it is now manufactured in the United States to the extent of over 2.4 gal. per capita annually. Since 1914 the total ice-cream production has increased almost 100 per cent, and in 1931 the United States produced over 300 million gallons. No longer a luxury, its value as a food, containing a goodly percentage of valuable nutritive constituents largely derived from dairy products, together with pleasant flavor and smooth texture, has won for this product an important and enduring place in the American dietary.

According to tradition, Marco Polo in his extensive Asiatic travels was the first European to experience the pleasure of frozen milk delicacies. Such products as were available in those distant centuries, as well as those made in recent decades in American homes, would doubtless prove poor competitors to the ice cream of today, which is largely manufactured in sanitary well-equipped establishments under careful technical control, with the help of especially designed freezers and homogenizers, which make possible a superior product.

The first ice cream made commercially in the United States appeared in Baltimore in 1851. At present, ice cream may be found even in many isolated regions, as most sizable communities have at least one ice-cream plant, and many of the larger metropolitan manufacturers ship products over an area of hundreds of square miles.

The main components of ice cream are milk products, which may be in the form of milk, skim milk, cream, condensed milk, dried milk, or butter. Various other ingredients may be added depending on the particular kind of ice cream to be made. Sugar is generally present in all ice creams.

Flavoring materials including extracts, fruits, fruit juices, or sirups are incorporated in some form. Nuts, ginger, rum, peanut brittle, and equally divergent substances are incorporated on occasion to make special flavors. Stabilizers are often incorporated in the ice-cream mix, and sometimes artificial coloring is added. Vanilla ice cream is by far the most popular flavor in spite of the large number of types now available. A few years ago one of the larger restaurateurs in Boston offered his customers beet-, carrot-, and spinach-flavored ice cream, but the acceptance of these colorful products has not been widespread.

Ice cream is defined in Massachusetts to be

> the frozen product of cream, milk or skimmed milk, or any combination thereof, or of milk products, with sugar, and with or without the addition of pure gelatine

or vegetable gums. Such product shall contain not less than ten per cent of milk fat and not less than eighteen and five tenths per cent of total milk solids; provided, that if eggs, fruit, fruit juices, cocoa, chocolate or nuts are added thereto, such product shall contain not less than eight per cent of milk fat and not less than sixteen and five tenths per cent of total milk solids.

The fat content cited in Massachusetts standards is lower than that in certain other states, however.

The composition of manufactured ice cream varies to a considerable extent. State laws with respect to this product are concerned largely with the butter-fat content, although even with this factor the minimum standards vary 100 per cent. Such a situation enables the manufacturer to produce an ice cream of a food quality which depends greatly on the trade for which it is intended. Fortunately the majority of the dealers and manufacturers have found it essential to make high-quality products, or those containing at least 12 per cent fat. Fruit, nut, and similar types of ice cream usually contain somewhat lower fat contents.

The quality of materials used in making ice cream should be of the highest not only because of considerations of health, which are of the utmost importance, but also because of the fact that substitution of inferior materials may be evident in the finished product. Flavor is an important factor in ice cream and must be constantly guarded. The cream and milk which are the most important ingredients should be free from the objectionable tastes and odors possible from feed, environment, containers, or microbic development. Excessive cream acidity (over 0.15 to 0.25 per cent) is objectionable because of possible action on the proteins present in the mix.

Sugar (cane or beet sugar), which besides sweetening the product and improving its texture also adds food value, may be present to the extent of 14 to 20 per cent of the mix, and may constitute 50 per cent of the total solids. The total solids excluding fat have the effect of improving texture in that they partially fix the free moisture. It is possible to substitute a part of the cane sugar by corn sugar (dextrose) which is less sweet and yet has the tendency to assist in producing fine texture, according to Turnbow and Rafetto,[1] although such practice is not common.

Lactose or milk sugar which, because of its origin, must be a constituent of ice cream if milk or concentrated milk products are incorporated, is generally present to the extent of less than 6 per cent in the mix. When present in much greater concentrations, lactose may produce what is known as "sandiness in ice cream." Sandiness is a gritty sensation experienced by the tongue when ice cream is eaten, and is due to lactose crystals which are formed in the product. Milk solids excluding fat are used to improve the texture of ice cream, but it is obvious that

[1] TURNBOW and RAFETTO, Ice Cream, New York, 1928.

there are limitations to such usage as in the dried form they contain a little over 50 per cent lactose. Any fluctuation in storage temperatures of the finished product is said to favor the development of lactose crystals. Low temperatures tend to decrease the rate of lactose crystallization.

A stabilizer is a substance employed to improve the texture of ice cream by forming a continuous gel or colloid structure which develops after the mix leaves the freezer. Such materials have an ability to adsorb water or adsorb the protein or fat of the mix, and are believed to retard the rate of crystal growth. Other terms used in the trade with the same significance are colloids, holders, and binders. (Another reason for the use of stabilizers is the fact that such materials tend to retard the melting of ice cream.)

Gelatin is the most commonly used stabilizer, although gums, starch, egg albumin, carob flour, Irish or Iceland moss, and alginic acid have been used for the same purpose. The use of certain so-called stabilizers may allow the entrance of dirt and many bacteria, which are not to be found in gelatin of high quality. These materials, if used, need be used only in very small quantities, usually but a fraction of 1 per cent of the mix. Excessive amounts lower the quality and affect the taste of the ice cream.

Pasteurization of the Mix.—Pasteurization of the ice-cream mix is an essential part of the process in all well-conducted establishments and is done to kill any objectionable or pathogenic microorganisms present. With the variety of components that are incorporated in an average mix and the divergence of their sources, the use of such a heat treatment eliminates the possibility of dangers of a microbic nature. This process is carried out by raising the temperature of the mix to 145 to 150°F. and holding it between these limits for a period of 30 minutes. Pasteurization is commonly carried out in large insulated holding tanks.

The viscosity of the cream is largely destroyed by pasteurization, and as viscosity is a valuable characteristic of an ice-cream mix, some means must be utilized to restore the viscosity as far as possible. This may be done: by holding the ice-cream mix for a period of hours at 32 to 36°F. ("ageing"); by the use of enzymes capable of acting on proteins; or by the use of an homogenizer. The latter method is most common, although many manufacturers allow the mix to age for some hours (12 to 48) after homogenizing.

The process of homogenization, which is a mechanical means of reducing the size of the fat globules in the mix, either cuts down or eliminates the time necessary for ageing the mix and improves the texture of the final product. The use of an homogenizer or viscolizer also prevents a partial churning of the fat in subsequent operations, enables the use of unsalted butter or butter oil as a source of fat if desired, and imparts

viscosity to the mix. Essentially the homogenizer is a mechanical means of forcing the mix through extremely small apertures under high pressure (sometimes 2,000 to 4,000 lb. per square inch), thereby reducing the fat globules to any desired size. The surface area of the fat globules is increased to a marked extent in this manner and enables greater adsorption of the proteins of milk present in the mix. Homogenizing at temperatures between 140 and 150°F. is believed most satisfactory and it is the usual custom to run the mix immediately into the homogenizer from the pasteurizing unit.

The ice-cream mix, subsequent to homogenizing or ageing, or a combination of the two processes, is cooled to at least 40°F. and run into the freezers. Higher initial temperatures may allow churning and cause a greasy texture. A freezer is a cylindrical refrigerated container into which the mix is placed for the purpose of cooling it very rapidly and evenly, and incorporating large volumes of air into the product. The freezers are usually batch freezers with a capacity of 10 gal., or 25 gal., and may be cooled by ice and salt mixtures (the oldest method but practically obsolete except in the home), by brine, or by direct expansion of ammonia. Brine temperatures may vary between 5° above and 5° below 0°F.

Within the freezer is a dasher which is constructed usually of two main parts, the scraper and the beater. As the primary purpose of the freezer is to conduct heat away from the ice-cream mix as rapidly as possible, the sharp blades of the scraper continuously scrape the inside of the freezer and remove any ice crystals which form on the walls. These crystals, if not removed, would tend to retard the heat transfer from the mix to the refrigerant. The beater is designed to incorporate air into the mix and thus separate the solids and at the same time produce the swell, or overrun, which may amount to from 10 to 100 per cent or more of the original mix. The air is enclosed in minute cells which must later have their walls frozen to retain the air. Without this swell or overrun ice cream would be a compact, comparatively unpalatable substance and not the light tasty delicacy that is enjoyed by so many millions each year. The beater generally rotates in the opposite direction from the scraping device. The dashers may be regulated to run at any speed but usually a rate between 175 to 225 revolutions per minute (r.p.m.) is used. The dasher also assists in discharging the mix from the freezer at the proper time.

Ice cream during the freezing process starts to swell at 34°F. and reaches a maximum at 28.5°F. At about 27°F. the swelling ceases, for the freezing point of the mix is usually between 26 and 28°F. During the freezing process only about 50 per cent of the actual freezing of the mix takes place, the rest is frozen in the hardening room. When the freezing

point has been reached and the consistency of the ice cream is still semi-solid or slushy, it is ready to be discharged from the freezer and placed in suitable containers or molds, according to the type of trade for which it is intended. Such containers should be prechilled in order to prevent melt-

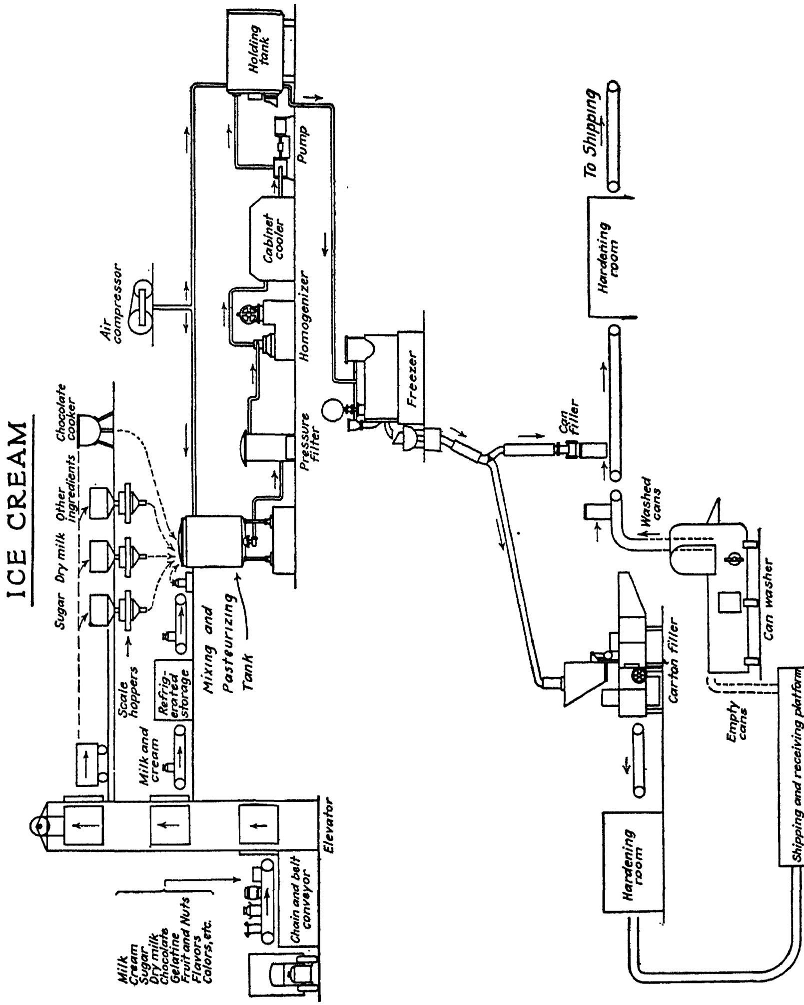


FIG. 47.—Flow sheet of ice-cream manufacture. (*Courtesy of Food Industries.*)

ing of the partially frozen cream at the areas of contact with a warm surface. The cell walls, in which the air is entrapped are still plastic and must be subjected to much lower temperature than that so far attained, (about 25°F.) in order to make them rigid. The containers, usually cans, are immediately transferred to the hardening room, maintained usually at subzero temperatures.

A more recent trend in hardening rooms is to use extreme low temperatures, from −35 to −50°F. with an air blast which freezes the cream in a much shorter time. Instead of 24 hours being required, the product may be hardened in a fraction of that time. This method enables the use of cartons, and smaller distribution units, rather than the somewhat cumbersome 5-gal. cans, and may be made automatic by means of a mechanical-conveyor system. After the product is completely hardened at the lower temperatures, it is stored at about 0°F.

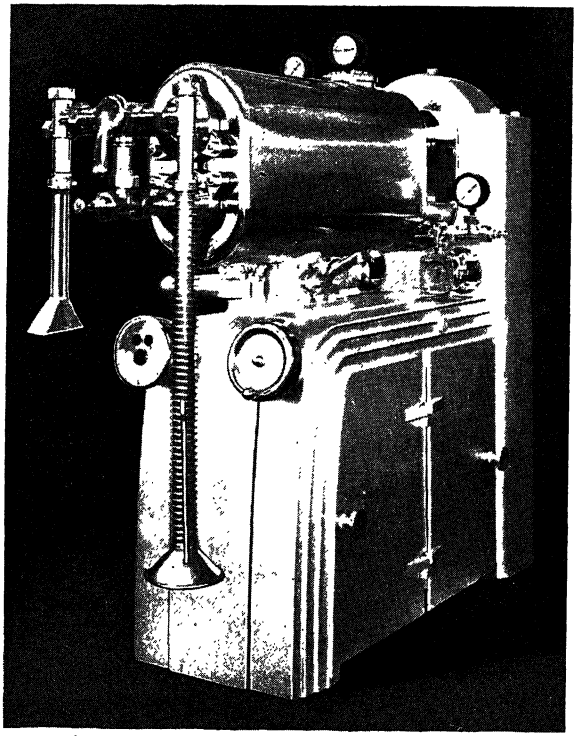


FIG. 48.—Vogt continuous ice-cream freezer. (*Courtesy of Cherry-Burrell Corp.*)

With recent advances in the quick-freezing of other foods some application has been made in the freezing of ice cream. Some manufacturers now use temperatures of −15°F. or lower in the freezers with the idea of getting more rapid freezing and smaller ice-crystal development, which tends toward smoothness.

Continuous Freezing Methods.—In contrast to the batch freezers, which are widely used, is the recent development of continuous freezers, taking a period of only 5 to 10 seconds for the freezing process. The mix is forced under pressure through a freezing tube equipped with a revolving

dash. Air is also incorporated into the mix under pressure and is whipped into the mix as it is being frozen. By the exposure of the mix against the refrigerated walls of the freezing tube in a very thin layer, it is possible to remove the heat at a rapid rate and to secure more uniform freezing. The discharge from the freezer is colder and stiffer than is possible using batch freezers, and as a result the product may be run directly from the freezer into packages of domestic size, which is a definite advantage.

The use of this method is said to result in a much finer air-cell structure and the development of much smaller ice crystals than are formed in batch freezers, both of which factors tend toward a product of much finer body, texture, and smoothness. The fact that the process may be continuous is also an advantage from the standpoint of operations.

Bacteriological examinations of ice cream are valuable in determining the sanitary quality of the product and may also afford some information regarding the quality of raw materials and the care used in the process. The proper cleaning of equipment used in ice-cream plants is as essential as in an establishment handling fluid milk. The freezers require particular attention as they may be thoroughly cleaned only with difficulty and are therefore much more likely to be neglected.[1]

The bacterial plate counts of frozen ice cream are often higher than the mix from which it is made. This seeming paradox, in view of the fact that low temperatures are inhibitive to many bacteria, is due to mechanical action. It is believed that the severe agitation produced by the revolving dasher tends to separate bacteria present in clumps or aggregates, which in the unfrozen mix would result in but one colony, whereas in the frozen product after beating the separated cells may give rise to many more individual colonies.

CHEESE

The manufacture of cheese is of ancient origin. This valuable food product is mentioned in the Bible and is believed to have been commonly produced during the earlier period of Greek and Roman civilization. It is said that the flocks and herds of the European monasteries were the sources of milk for cheese production during later years and that the art of cheese making was fostered and spread by the monks who were the teachers of that period. Every part of the world in which milk-producing animals are maintained has learned of the importance of cheese making, and many of these areas and countries have specialized in some particular type of cheese which is highly prized. In some instances these types have become world-famous and thereby the region or country has come

[1] DAHLBERG and MARQUARDT, Sterilization of Ice Cream Freezers. *New York State Exp. Sta. Bull.* 628, 1933.

to be associated with the production of specific types, although they may produce others equally desirable.

Switzerland, France, Italy, England, Holland, and Belgium are each noted for particular types of cheeses, the manufacture of which has attained the magnitude of large industries requiring the services of thousands of people and the milk of millions of animals. Cheese constitutes an important part of the dietary of many Europeans, and although it is not used to so great an extent in the United States, the amount consumed here appears to be increasing somewhat in recent years. The per capita consumption of cheese in the United States is from 3 to 4 lb. per year, or about one-fourth that of butter.

Cheese Definitions.—Cheese is defined by the U. S. Department of Agriculture[1] as: "The product made from curd obtained from the whole, partly skimmed or skimmed milk of cows, or from the milk of other animals, with or without added cream, by coagulating the casein with rennet, lactic acid, or other suitable enzyme or acid, and with or without further treatment of the separated curd by heat or pressure, or by means of ripening ferments, special molds, or seasoning."

In the United States the name cheese unqualified is understood to mean Cheddar cheese, American cheese, American Cheddar cheese.

Whole milk cheese is cheese made from whole milk.
Partly skimmed milk cheese is cheese made from partly skimmed milk.
Skimmed milk cheese is made from skimmed milk.

Whole Milk Cheese

Cheddar cheese, American cheese, American Cheddar cheese, is the cheese made by the Chedder process from heated and pressed curd obtained by the action of rennet on whole milk. It contains not more than 39 per cent of water, and in the water-free substance, not less than 50 per cent of milk fat.

Pineapple cheese is the cheese made by the pineapple Cheddar cheese process from pressed curd obtained by the action of rennet on whole milk. The curd is formed into a shape resembling a pineapple, with characteristic surface corrugations, and during the ripening period the cheese is thoroughly coated and rubbed with a suitable oil, with or without shellac. It contains, in the water-free substance, not less than 50 per cent of milk fat.

Limburger cheese is the cheese made by the Limburger process from unpressed curd obtained by the action of rennet on whole milk. The curd is ripened in a damp atmosphere by special fermentation. It contains, in the water-free substance, not less than 50 per cent of milk fat.

Brick cheese is the quick-ripened cheese made by the brick-cheese process from pressed curd obtained by the action of rennet on whole milk. It contains, in the water-free substance, not less than 50 per cent of milk fat.

[1] S.R.A.F.D. 2, Rev. 4, August, 1933.

Stilton cheese is the cheese made by the Stilton process from unpressed curd obtained by the action of rennet on whole milk, with or without added cream. During the ripening process a special blue-green mold develops, and the cheese thus acquires a marbled or mottled appearance in section.

Gouda cheese is the cheese made by the Gouda process from heated and pressed curd obtained by the action of rennet on whole milk. The rind is colored with saffron. It contains, in the water-free substance, not less than 45 per cent of milk fat.

Neufchatel cheese is the cheese made by the Neufchatel process from unheated curd obtained by the combined action of lactic fermentation and rennet on whole milk. The curd, drained by gravity and light pressure, is kneaded or worked into a butterlike consistence and pressed into forms for immediate consumption or for ripening. It contains, in the water-free substance, not less than 50 per cent of milk fat.

Cream cheese is the unripened cheese made by the Neufchatel process from whole milk enriched with cream. It contains, in the water-free substance, not less than 65 per cent of milk fat.

Roquefort cheese is the cheese made by the Roquefort process from unheated unpressed curd obtained by the action of rennet on the whole milk of sheep, with or without the addition of a small proportion of the milk of goats. The curd is inoculated with a special mold (*Penicillium roqueforti*) and ripens with the growth of the mold. The fully ripened cheese is friable and has a mottled or marbled appearance in section.

Gorgonzola cheese is the cheese made by the Gorgonzola process from curd obtained by the action of rennet on whole milk. The cheese ripens in a cool, moist atmosphere with the development of a blue-green mold and thus acquires a mottled or marbled appearance in section.

Whole Milk or Partly Skimmed Milk Cheese

Edam cheese is the cheese made by the Edam process from heated and pressed curd obtained by the action of rennet on whole milk or on partly skimmed milk. It is commonly made in spherical form and coated with a suitable oil and a harmless red coloring matter.

Emmenthaler cheese, Swiss cheese, is the cheese made by the Emmenthaler process from heated and pressed curd obtained by the action of rennet on whole milk or on partly skimmed milk, and is ripened by special gas-producing bacteria, causing characteristic "eyes" or holes. The cheese is also known in the United States as "Schweizer." It contains, in the water-free substance, not less than 45 per cent of milk fat.

Camembert cheese is the cheese made by the Camembert process from unheated unpressed curd obtained by the action of rennet on whole milk or on slightly skimmed milk, and ripens with the growth of a special mold (*Penicillium camemberti*) on the outer surface. It contains, in the water-free substance, not less than 45 per cent of milk fat.

Brie cheese is the cheese made by the Brie process from unheated unpressed curd obtained by the action of rennet on whole milk, on milk with added cream,

or on slightly skimmed milk, and ripens with the growth of a special mold on the outer surface.

Parmesan cheese is the cheese made by the Parmesan process from heated and hard-pressed curd obtained by the action of rennet on partly skimmed milk. The cheese, during the long ripening process, is coated with a suitable oil.

Skimmed Milk Cheese

Cottage cheese, Schmierkäse, is the unripened cheese made from unheated (or scalded) curd obtained by the action of lactic fermentation or lactic acid or rennet, or by any combination of these agents, on skimmed milk, with or without the addition of buttermilk. The drained curd is sometimes mixed with cream, salted and sometimes otherwise seasoned.

Whey Cheese

Whey cheese (so-called) is produced by various processes from the constituents of whey. There are a number of varieties, each of which bears a distinctive name, according to the nature of the process by which it has been produced, as, for example, "Ricotta," "Zieger," "Primost," "Mysost."

Pasteurized Cheese and Emulsified Cheese

Pasteurized cheese, pasteurized-blended cheese, is the pasteurized product made by comminuting and mixing, with the aid of heat and water, one or more lots of cheese into a homogeneous, plastic mass. The name "pasteurized cheese," "pasteurized-blended cheese," unqualified, is understood to mean pasteurized Cheddar cheese, pasteurized-blended Cheddar cheese, and applies to a product which conforms to the standard for Cheddar cheese. Pasteurized cheese, pasteurized-blended cheese, bearing a varietal name, is made from cheese of the variety indicated by the name and conforms to the limits for fat and moisture for cheese of that variety.

Emulsified cheese, "process cheese," is the modified cheese made by comminuting and mixing one or more lots of cheese into a homogeneous, plastic mass, with the aid of heat, with or without the addition of water, and with the incorporation of not more than 3 per cent of a suitable emulsifying agent. The name "emulsified cheese," "process cheese," unqualified, is understood to mean emulsified Cheddar cheese, process Cheddar cheese, and applies to a product which contains not more than 40 per cent of water and, in the water-free substance, not less than 50 per cent of milk fat. Emulsified cheese, process cheese, qualified by a varietal name, is made from cheese of the variety indicated by the name, and conforms to the limits for fat and moisture.

In addition to Cheddar cheese which is the most important type produced in this country, large quantities of cheese of other kinds are produced. Some of these resemble in character certain of the European cheeses which are imported in large quantities. Within the last decade the manufacture of processed cheese of numerous kinds, largely packed in small-unit packages, has become of great importance and constitutes a considerable portion of the domestic consumption of cheese.

The names of a few of the more popular imported cheeses and their general origin are given below. The types may be manufactured over wide areas at present, rather than in the town, district or country where they received their name but represent a general type of process or manufacture instead. A number of these types are now made in the United States also.

Brie—northwestern France
Camembert—Camembert, France
Cheddar—Cheddar, England
Edam—town near Amsterdam, Holland
Emmenthaler—Switzerland
Gorgonzola—northern Italy
Gouda—Holland
Gruyère—Switzerland
Limburger—Belgium
Neufchatel—Switzerland
Parmesan—Parma, Italy
Roquefort—France
Stilton—England

The largest quantities of cheese imported by the United States come from Italy and Switzerland.

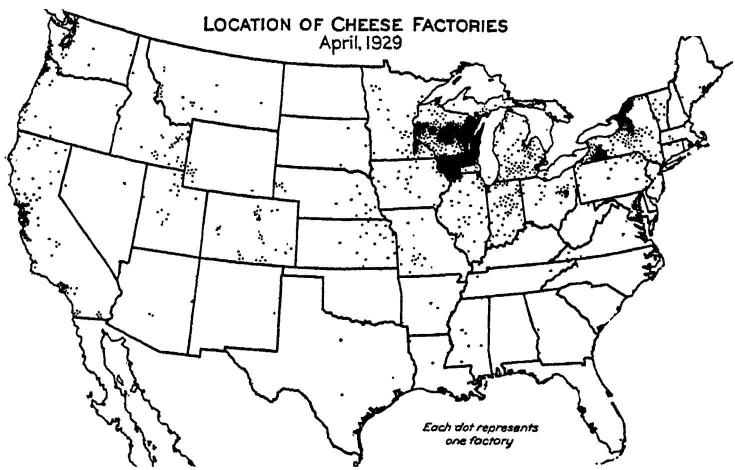


FIG. 49.—Since Wisconsin produces over 70 per cent of the nation's cheese, it may be more interesting to note where in Wisconsin, and other states, the cheese is produced than to compare the production of the different states. In southwestern Wisconsin most of the foreign cheese of the United States is made, principally Swiss and Limburger. In eastern and north-central Wisconsin, also in Grant and Richland Counties in southwestern Wisconsin, practically the entire production is American cheese, a modified Cheddar type. New York produced about 16 per cent of the nation's cheese in 1919, but in 1927 only 8 per cent, nearly all American cheese. The two centers of production are the St. Lawrence Valley and southward to the Mohawk Valley and the southwestern area, located mostly in the hills. (*U. S. Dept. Agr.*)

The making of cheese in this country was carried on largely in farm homes until the middle of the last century, since which time an increasing proportion has been manufactured in factories. At present cheese is almost exclusively a factory product in this country, made under sanitary

conditions and technical supervision. Wisconsin, because of its large milk supply and its relative distance from fluid milk-consuming centers, is the leading production state. New York, which was at one time the leader, produces between 10 and 15 per cent of the annual production of Wisconsin. Oregon, Minnesota, Idaho, and Michigan are also important producers of Cheddar cheese, but Wisconsin furnishes about 70 per cent of our national production, which amounted in 1931 to over 375 million pounds.

Some of these factories are cooperatives which are owned by the numerous farmers that supply the milk and share mutually in the profits. The first factory of this type was started in Wisconsin in 1841 and it is estimated that about 25 per cent of the United States production is now produced by cooperatives. One cooperative association which is said to control about 350 factories produces and merchandises approximately 40 million pounds of cheese annually.[1]

TABLE 92.—CHEESE: UNITED STATES IMPORTS OF ALL TYPES OF CHEESE BY COUNTRIES (1,000 lb.)

Country of origin	1924	1926	1928	1930
Italy	31,256	35,026	38,008	33,258
Switzerland	13,632	16,736	18,564	17,947
France	4,444	5,424	6,663	4,983
Canada	984	11,835	7,488	3,143
Netherlands	2,899	3,471	3,712	2,541
Greece	1,817	2,570	2,788	1,830
Other countries	4,144	3,355	4,180	4,609
Total	59,176	78,417	81,403	68,311

TABLE 93.—CHEESE: IMPORTS FOR CONSUMPTION IN THE UNITED STATES*

Calendar year	Quantity, lb.	Value
1923	61,103,991	$19,912,162
1924	59,812,306	17,787,585
1925	62,620,250	17,559,591
1926	75,868,142	20,375,899
1927	80,796,326	24,700,517
1928	79,946,664	24,300,551
1929	76,343,639	22,379,821
1930:		
Jan. 1 to June 17	41,665,681	11,517,624
June 18 to Dec. 31	27,292,844	7,121,728

* U. S. Dept. Agr. Bureau of Agricultural Economics.

[1] BARTLETT, R. W., Cooperation in Marketing Dairy Products, 1931.

Considerable difference exists in different varieties of cheese from the standpoint of chemical composition, as may be seen in Table 94. Those varieties of the so-called hard type are generally higher in protein and may also have high fat contents. The softer types, which contain more water, are correspondingly low in protein, but the fat content depends on the particular process and whether cream, whole milk, or skim milk is used.

TABLE 94.—AVERAGE COMPOSITIONS OF A FEW OF THE MORE COMMON CHEESES (As Given by Associates of Rogers, Fundamentals of Dairy Science)

Cheese	Water	Protein	Fat	Lactose and ash
American Cheddar....	37.33	23.39	33.41	5.89
Domestic Swiss......	30–34	26–30	30–34	3–5
Parmesan...........	32.16	43.34	19.13	6.29
Roquefort...........	38.69	21.39	32.31	6.14
Camembert..........	47.91	19.66	27.33	....
Cottage.............	71.4–79.9	12.7–21.1	0.4– 1.9	0.8–2.5
Cream..............	38.0–43.0	13.0–16.0	43.0–48.0	0.5–1.25
Neufchatel (domestic)	50.0–55.0	18.0–21.0	23.0–28.0	0.5–1.25

Milk from cows is used in American cheese manufacture, although in Europe goat's milk and ewe's milk are commonly used in some districts. Regardless of the source of the milk, the fundamental considerations are the same, namely, the coagulation of the most important milk protein, casein, and the retention of the fat and other insoluble constituents, together with some water. The excess water is eliminated by heating or manipulating the curd in various ways such as cutting, draining, pressing, etc. The amount of water eliminated determines in part the type of cheese, *i.e.*, whether it will be hard or soft. The soft varieties are allowed to retain a larger amount of water.

The flavor and aroma of any cheese, as well as its texture, depend in large part on those chemical changes brought about by the microorganisms present in the milks used, and the enzymes which they produce. These chemical reactions require careful control from the standpoint of temperature, acidity, and oxygen content, and differ depending on the particular enzymes or microorganisms concerned. The predominating flora of microorganisms present in the raw milk is of great importance when no cultures of specific bacteria or molds are introduced. Cultures of bacteria or molds are introduced in the production of some varieties of cheese in order to obtain the particular flavor or aroma and to ensure the qualities of the final product. A notable example of this sort is the manufacture of Roquefort cheese to which are added the spores of *Penicillium roqueforti* in order to attain characteristic products.

The first step in making any cheese is the coagulation of the protein. This may be accomplished in two ways, the first and most natural being to allow the milk or skimmed milk to stand until the bacteria present increase in numbers and eventually coagulate the casein owing to the lactic acid they form by action on the milk sugar, lactose. In order to ensure predominance of the most desirable types of acid-forming bacteria, a pure culture or starter of favorable organisms of the *Streptococcus lactis* types may be added. The second method is to bring about the coagulation of the casein by the addition of an enzyme, rennet, derived from other sources. This is not usually added until the proper acidity for its action has been attained in the milk. Rennet is needed in only very small quantities as one part of this enzyme can coagulate 2 million parts of fresh milk. There are numerous theories regarding the colloidal and physical phenomena involved in the coagulation of casein[1] which depend not only on the type of milk and the pH of the milk, but also on the temperature of the milk, the concentration of rennet used, and possibly other factors. Commercial rennet is obtained from an extract of the lining of calves' stomachs.

In this country rennet is commonly used as a coagulating agent, and in order to obtain optimum conditions for coagulation the acidity of the milk is brought to approximately 0.2 per cent and the milk raised to a temperature of about 85°F. Under these conditions the coagulation should be complete in less than half an hour. The milk is agitated while the diluted rennet is mixed with the milk in order to obtain complete coagulation and curd formation.

If Cheddar cheese is to be made, the curd resulting from the rennet coagulation is divided into small cubes by means of cheese knives which are constructed of wire spaced at intervals of approximately ½ in., and are drawn through the curd. One knife has vertical wires, the other has wires in a horizontal plane so the strips made by the first knife are cut into cubes by the operation of the second.

The cut sections of curd and the residual liquid from the milk, called whey, is heated by means of a hot-water jacket until the whey reaches body temperature during which time the contents are stirred with a wooden rake. The heat causes the loss of liquid or whey from the curd and a proportional shrinkage in bulk of the coagulated casein.

When the heating is completed the liquid is allowed to drain through a screen. The curd is heaped up and mats together into a compact mass which adheres tenaciously. This mass is cut into strips with a knife. After the strips are handled several times to facilitate the removal of more whey, they are piled together and the curd again fuses into an almost homogeneous mass.

[1] Clayton, Colloid Aspects of Food Chemistry and Food Technology, 1932.

A curd mill or mechanical cutting device is next employed to cut up the curd into small strips, after which salt is added to the strips and they are packed into forms or hoops and pressed into the familiar shapes known in this country. During milling and pressing more water is removed from the curd, which is in a covering of cheese cloth which had previously been lined in the hoop before the curd was added. The pressing operation is done slowly and may take 24 hours or more. The amount of moisture remaining and the quantity of salt added influence the changes which occur in the later curing processes as they determine in part the predominance of microbic flora which are capable of acting during this period. A second pressing may follow, after which the cheese is dipped in hot paraffin to form a relatively impervious protective layer on all surfaces. This lessens subsequent moisture losses and accomplishes a surface heat treatment sufficient to cut down molds.

These operations have not brought to a completion all the changes which are necessary in making a finished cheese with the texture, flavor, and aroma which characterize a fine Cheddar cheese. The chemical changes necessary for these essential characteristics require the action of bacteria, and all the manufacturer can do is to place the cheese at the proper temperature and let the microorganisms present in the cheese do their work. These biochemical reactions may be controlled to a certain extent by temperature because both the growth of the bacteria and the chemical action of the enzymes they produce are accelerated by high temperatures. Thus if the curing time is to be short, temperatures as high as 65°F. may be used but lower temperatures, 35 to 50°F., for longer periods of time are more likely to produce cheese of higher quality.

These bacterial changes are influenced by the flora present in the original milk and emphasize the necessity of having a clean milk produced under sanitary conditions because otherwise the likelihood of off-flavors due to other bacteria is increased greatly. Lactic-acid-producing types of bacteria are normally present in clean milk and the acidity produced by such types tends to inhibit many undesirable organisms. Such types appear to perform only one part of the changes in cheese and act primarily on the lactose. A subsequent increase in other types may eventually displace the lactic acid streptococci and bring about the partial hydrolysis of casein thus contributing to the formation of the characteristic aromatic and flavoring compounds desired in this type of cheese.

The first stage in the ripening of Cheddar cheese is concerned with the digestion of the curd, comprised largely of casein, which is tough, rubbery, and insoluble in water. Enzymes and the presence of lactic acid cause a proteolysis of the casein with the formation of proteoses and other breakdown products such as amino acids, also gaseous carbon dioxide and ammonia, thus causing changes in solubility and digestibility. These

changes are not responsible for the principal characteristic flavors in the cheese, however. Simultaneously, other changes are taking place which are responsible for the flavors. Acetic and propionic acids are produced by fermentation of the lactates. Ethyl alcohol, which is also produced by fermentation, combines with the acids to form esters which create the characteristic flavors.

When the proper degree of curing has been reached, the cheese is placed in refrigerated warehouses for future consumption or is distributed to the usual trade channels.

The market value of cheese depends not only on flavor but also on its body and texture, color, and finish. Both flavor and body are dependent in part on the types of bacteria present in the original milk, as improper bacterial species may cause the presence of gas holes which are not present in Cheddar products of the highest quality. Body is also dependent in part on the mechanics of the various operations because faulty handling may result in poor texture. The color, if not that of the original milk pigments, is the result of adding an approved cheese color previous to the rennet treatment of the milk and should be of uniform concentration all through the cheese. Otherwise an uneven concentration detracts from the quality of the product. Finish is concerned with the external appearance of the cheesecloth bandage and the cheese surface, therefore reflecting the care taken in preparing the final product. Any roughness, wrinkles, dirt, or mold lower the value of the whole cheese regardless of the quality of the interior.

TABLE 95.—CHEESE: DOMESTIC PRODUCTION BY VARIETIES AND BY PRINCIPAL PRODUCING STATES, 1929
(1,000 lb.)

Principal state	American or Cheddar	Swiss or Emmenthaler	Brick and Münster	Limburger	Cream and Neufchatel	Italian varieties	All other varieties	Total
Wisconsin	242,841	16,419	30,219	5,163	8,356	1,521	658	305,172
New York	26,641	381	547	2,736	18,930	1,947	2,998	54,180
Oregon	12,585	......	46	.....	351	1	1	12,984
Minnesota	10,979	......	1	507	......	.....	.....	11,487
Indiana	9,860	245	21	.....	......	2	.....	10,128
Michigan	8,735	35	123	39	3	18	360	9,313
Idaho	7,327	337	......	.....	......	.....	.....	7,664
Illinois	6,070	519	393	8	4,987	104	239	12,311
California	4,582	239	14	9	776	2,146	1,534	9,300
Ohio	1,114	1,053	88	.....	2	.....	752	3,009
All other	45,605	178	311	106	1,009	209	967	48,385
Total	376,339	19,406	31,763	8,568	34,405	5,948	7,504	483,933

TABLE 96.—CHEESE: UNITED STATES EXPORTS TO PRINCIPAL COUNTRIES
(1,000 lb.)

Country of destination	1924	1926	1928	1930
Canada	173	248	155	197
Panama	359	441	402	449
Other Central American countries	273	283	287	261
Mexico	872	797	522	325
Cuba	1,146	850	365	122
Other West Indies and Bermuda	444	591	334	257
South America	46	225	128	105
China, Hong Kong, and Kwantung	180	286	141	41
Philippine Islands	100	115	149	134
Other countries	706	67	77	73
Total	4,299	3,903	2,560	1,964

The processing of Cheddar cheese, which seems to be a method destined for increased use in the future, owing to the present popularity of products of this nature, consists of removing the rind of a mature cheese and further treating the product. The cheese is ground, water and an emulsifying agent such as sodium citrate added, and the mixture heated with continuous agitation. The resulting emulsion is poured into tinfoil-lined wooden boxes or other containers to harden and later be packed. The heating process used is sufficient to destroy a large proportion of the bacteria present and inactivate the enzymes, thereby eliminating further changes to a considerable extent.

Processing enables the blending of cheeses of varying flavors, of cheeses of different types, and the resulting products can therefore be made to suit any palate. It has been estimated that about one-third of all cheese produced in the United States is now packaged. The convenience of the small domestic package and the keeping qualities of cheese so packed have proved of value in increasing the more common usage of cheese.

In 1934, Dr. Rogers of the Bureau of Dairy Industry, U. S. Department of Agriculture, announced a method of packing Cheddar cheese in tin cans in which the ripening process takes place.[1] The use of the tin container prevents the evaporation of moisture, prevents the formation of a rind, and inhibits mold growths which are undesirable. The use of a can with a "one-way check valve" permits the escape of carbon dioxide and other gases that may be evolved during the ripening process, but prevents excessive moisture losses.

In preparing the cheese for the can, the curd is wrapped in cheesecloth and pressed in suitable hoops for the desired shape of the can. After

[1] ROGERS, L. A., *Food Ind.*, **6**, 308, 1934.

about a day in the hoops the cheesecloth wrapping is stripped off and substituted by one of parchment paper or cellophane which serves as a liner for the can and prevents any discoloration which might result from the contact of the cheese with unprotected can surfaces. Lacquer-lined cans are used, as sulphides may be produced during the ripening process, and with unlacquered cans the sulphides are likely to produce dark discoloration on combination with the metal of the can.

The cans are sealed and packed in proper shipping containers and stored for the ripening process, during which temperatures from 45 to 50°F. are considered most satisfactory.

Swiss or Emmenthaler Cheese.—Swiss or Emmenthaler cheese is termed a hard cheese, as is Cheddar cheese and Parmesan cheese from Italy, in distinction to the semi-soft Camembert, Roquefort, and brick cheeses and the soft Neufchatel and cream cheeses which contain higher moisture percentages.

The appearance of Swiss cheese is noted for its characteristic holes which are due to the development of gas caused by bacterial action and the entrapping of this gas in the curd. In the United States it is customary to add pure cultures of bacteria to the milk at the start to ensure the necessary production of lactic acid. One of the cultures used for this purpose is *Lactobacillus bulgaricus*. Two other pure cultures may also be added, *Lactobacillus casei* and *Bacterium acidi propionici* which are important in producing the final flavors and the gas resulting in the holes or eyes.[1] The production of this type of cheese is somewhat more involved than that of Cheddar cheese as, after the coagulation by rennet takes place, the curd is cut twice and then reduced to small particles before being cooked. A salt-brine treatment, during which the cheeses are submerged for several days, follows the pressing and salting operations. The proper action of bacteria in the product is of the utmost importance as otherwise bad flavors and holes which are not of the desired type may result.

In a study of the bacteria in products from eight different cheese factories in Switzerland, the predominant organism was found by Erekson and Dorner[2] to be *Streptococcus thermophilus* which is capable of growing at higher temperatures than most bacteria. In one case *Streptococcus lactis* was in greatest numbers, but the cheese was inferior.

In 1930–1931 over 15 million pounds of Swiss cheese were imported and constituted over 25 per cent of our total cheese importations for that year. During the same year large quantities of products similar in

[1] Eckles, Combs, and Macy, Milk and Milk Products, McGraw-Hill Book Company, Inc., 1936.

[2] Erekson, A. B., and W. Dorner, *J. Bact.*, **29**, 70, 1935.

character were produced in domestic factories, which indicates the popularity of this type of cheese in America.

Roquefort Cheese.—Molds assume a leading role in the ripening of some types of cheese, such as Camembert, Brie, Roquefort, Gorgonzola, and Stilton. The making of Roquefort in its original home in France differs somewhat from the methods common in this country, although the final product is said to be closely comparable. The American methods, as used in a plant producing Roquefort cheese in Pennsylvania, are briefly as follows.[1]

Sweet, raw milk, to which 4 per cent of lactic starter is added, is brought to an acidity of 0.20 to 0.22 per cent and then the temperature is raised to 83 to 85°F., when rennet is added. After setting 1 to 1½ hours the curd is cut into 1-in. sections and dipped with scoops into an adjoining vat which has racks covered with cheesecloth which allow the curd placed thereon to drain. After about half an hour the curd is placed in sterilized hoops and heaped up but not pressed. These metal hoops, much smaller than those used for Cheddar cheese, have 150 1/16-in. holes through the sides. When filling the hoops, the mold culture of *P. roqueforti* is sprinkled in between layers of curd. The culture was grown previously in loaves of rye bread which were later dried and pulverized so that a fine powder of bread and mould could be used as an inoculant for the curd. The forms containing curd are transferred to a room at 65 to 68°F. and a relative humidity of 80 to 90 per cent. After 15 minutes the forms are inverted. The next day the forms are removed. Subsequently the cheese is washed in salt water, which treatment is repeated for several days until they are treated with dry salt which is rubbed in by hand. During the salting period of approximately 10 days the cheese is kept at about 48°F., after which it is placed in a curing room at 45 to 50°F. with a relative humidity of 83 to 89 per cent until the cheese is 2 months old. Twice previous to the curing period at high humidity the cheese is scraped, and immediately before this, the cheese is mechanically perforated with many small holes to allow the entrance of air which is necessary for the desired mold growth to progress through the interior of the cheese. After two additional months' storage the cheese is again scraped, then tinfoiled and ripened another 3 to 4 months.

American cheese of the Roquefort variety is made from cows' milk, although in France sheep's milk is generally used. The damp caves of France are substituted by artificial humidity and controlled temperature to favor proper curing by aid of the activities of the mold *Penicillium roqueforti*. After the curing is complete, the product is stored at temperatures slightly above freezing. The flavors are believed to be due to acids such as caproic, caprylic, and capric acids, or their derivatives.

[1] Flint, R. R., *Food Ind.*, **2**, 216–218, 1930.

Cottage cheese and Neufchatel cheese differ from those mentioned previously as no ripening process is employed. The flavor and texture are brought about by the lactic fermentation. The milk or skim milk is coagulated by acid, cut, heated to about 100°F., and then drained in cloth bags, after which it may be salted and packed. Its high water content favors bacterial spoilage and therefore it cannot be kept for extensive periods like most other cheeses. The use of a lactic starter or the pasteurization of the milk previous to coagulation is helpful in lessening spoilage due to other bacteria.

Neufchatel and Cream Cheese.—At the present time the soft cheeses such as Neufchatel and cream cheese are generally made from pasteurized milk in order to eliminate as far as possible the gassy and otherwise undesirable fermentations which are likely to occur in raw untreated milk, particularly in warm weather. Pasteurization also obviates any danger from tubercle bacilli which might be present, although all cheese should preferably be made from clean, fresh milk from tuberculin-tested cows. For Neufchatel cheese whole milk is commonly used, while for cream cheese the milk is fortified with fat so that it contains 6 to 8 per cent fat. Either the usual holder-type method of pasteurization or the high temperature short-time "flash" method may be used for this purpose. Homogenized milk is not considered satisfactory for cream cheese making.

After pasteurization the milk is cooled to approximately 80°F. (83°F. for cream cheese), and a lactic acid culture or starter is added to the extent of 1 to 1.5 per cent. Commercial liquid rennet is added in sufficient quantity and the milk is immediately filled into "shotgun" cans having a capacity of about 4 gal. each. For Neufchatel cheese $\frac{1}{3}$ oz. of rennet or $\frac{5}{6}$ gram of powdered pepsin will suffice, whereas for cream cheese $\frac{1}{2}$ oz. of liquid rennet or 1 gram of pepsin is needed. These are allowed to stand for 15 or 18 hours while the curd is formed and the fermentation or ripening processes take place. Then the cans are emptied carefully onto draining cloths made of cotton sheeting which is spread over racks. Care is taken to prevent the loss of cream with the whey and the curd is disturbed or broken up as little as possible. About 3 hours are required for proper draining of the curd. During the first part of this period the curd is not disturbed, in order that the excess whey may escape and the curd become a little stronger. Later the curd is pushed from the sides of the cloth, where it was originally poured, toward the center, then the cloth is placed in a rack with a flat bottom and the sides and ends folded over the curd so that the cloth and its contents resemble a filled bag. The bags are stacked on top of each other for a short time in racks, after which they are placed in a press where more whey and some air are pressed out mechanically. If the bags are not to be pressed within a few hours,

they are piled with alternate layers of cracked ice so the curd will be cooled and hardened, which facilitates the subsequent pressing operations. The pressing is usually continued until the yield for cream cheese is 18 to 20 lb. or for Neufchatel cheese is 14 to 16 lb. from 100 lb. of milk.

The curd from the presses is mixed with salt to the extent of 0.75 to 1.5 per cent and then passed through a grinding machine or a mechanical mixer, similar to a bread mixer. If the latter is used, the cheese must be later refrigerated before moulding. The moulding operation is usually accomplished by a mechanical device which forces the cheese through a moulding tube and out of an orifice, where an automatic cutting device cuts the pieces into appropriate lengths for packages. For best results the cheese should be fed into the moulder at a temperature of about 50°F.

These soft types of cheeses, to which various other materials such as chopped pimentos, chopped olives, chopped pineapple, or similar mixtures are added, may be filled into jars instead of moulded in bars or packages. The packages are usually wrapped in tin or aluminum foil.[1]

The best storage temperatures for cheeses of this type are between 40 and 50°F.

[1] *U. S. Dept. Agr. Bull.* 669.

CHAPTER XIII

BAKING

BREAD

Bread in some form is undoubtedly the world's most widely used food. In the United States the making of loaf bread, involving the use of yeast, and the many other special forms of bread, is now carried out to a great extent in large commercial bakeries, whereas 50 years ago most of the bread used in this country was made in each individual home or in small bakeries and shops. The transition has been from a domestic operation, which produced a few loaves at a time, to the small bakery, and thence to a highly developed industry which can prepare many thousand loaves of bread in one plant in a day. In addition to bread, many special types of rolls and also many kinds of cake have become factory products. The advantages from the standpoint of uniformity and quality of product and general sanitary handling are obvious.

The manufacture of a high-grade bread requires the use of raw materials of the highest quality. Flour, salt, water, and yeast are the primary requisites for the most ordinary kinds of wheat bread. Sugar, shortening, malt extract, milk, mineral salts, and other ingredients may also be utilized.

The largest single component of bread is flour, and for this reason the choice of a proper flour for bread making is of considerable importance. The characteristics of any particular lot of flour are dependent on the type of wheat from which it was made, and the chemical and physical properties of that type of wheat. In general, no one type of wheat possesses all the desirable characteristics deemed necessary, so various varieties of wheat are blended in different proportions in order to obtain the best results.

The dough made from flour, water, and other ingredients of bread becomes a colloidal mass consisting of particles of starch and protein which have thin layers or surface films of water covering them, the water thus forming a continuous phase. It is thought by some workers that the gluten component also forms a second continuous phase. The use of shortening agents causes fat adsorption at the interfaces, thus lessening the cohesion otherwise existing between particles. The reactions which may occur in dough between the various particles in these systems is dependent on the enzymes present in the flour and the yeast, the size and character of the protein and starch particles, temperature conditions, pH,

the fermentation by yeast and gas evolution, the amount of sugar available, the presence of inorganic salts, and doubtless other factors. The complexity of these changes is great, and the influence of each factor is difficult to determine.[1]

In order to have the best product, laboratory-scale baking experiments are often continuously carried out to determine what seem to be the optimum proportions of ingredients to use for each variety of product, as well as the best methods for utilizing the different wheats available, since the latter vary from season to season.

The making of bread is, therefore, much more than the mixing and baking of the various ingredients which are used. If simple mixing were all that took place previous to the baking process, the resulting material would doubtless be soggy, heavy, disagreeable, and possibly unpalatable. One very important function in the making of bread is to create a dough which will rise properly, one in which the yeast, when thoroughly incorporated, will be able to carry on its fermentation activities rapidly with the evolution of considerable quantities of carbon dioxide gas. This carbon dioxide gas is invaluable to the baker because it is normally trapped in the glutinous dough in small bubbles and thereby assists in lightening the entire mass. If the carbon dioxide were all allowed to escape, the resulting bread would be compact, tough, and heavy. Certain flours low in gluten content lack the ability to retain sufficiently the carbon dioxide evolved by the yeast and as a result are not desirable for bread making unless mixed with other flour which has a higher gluten content. This indicates the necessity of blending various flours, to combine in correct proportion those which have different properties, in order to obtain the best results.

The various operations in the making of bread may be outlined in the following manner:

1. Sifting the flour.
2. Mixing the dough.
3. Fermenting and conditioning the dough in troughs.
4. Dividing the dough.
5. Rounding up the dough.
6. Short proofing the dough.
7. Panning.
8. Proofing in the pan.
9. Baking.
10. Cooling.
11. Slicing.
12. Wrapping.

[1] For a survey of the literature of colloids in cereals and bread see Clayton, Colloid Aspects of Food Chemistry and Technology, 1932.

Sifting serves to remove foreign material, such as lint, husks, or bits of foreign matter which are present in the flour by accident. It also aerates the flour and lightens it by breaking up lumps and at the same time tends to make the flour more uniform in character.

Weighing is an important part of the process because in order to get uniform results it is necessary to have accuracy in the proportion of the various ingredients used. Inaccuracy means inefficiency, and inefficiency indicates waste.

Methods of Bread Making

Two principal methods of bread making are in general use, the straight-dough method and the sponge method. In the straight-dough method, which was the one more commonly employed until recently, all the ingredients which go into the dough are mixed together at one time and the dough is processed from that time on in a uniform manner. The sponge method, which is also known as the sponge and dough method, involves the mixing of some of the flour, water, yeast, and possibly some of the sugar, malt extract, shortening, etc., to form a "sponge" or active culture. The sponge is permitted to rise to a greater extent than the straight dough, after which the remainder of the ingredients are mixed together with it and allowed to rise for a short time, then the usual procedure is followed. In the past few years the sponge method has gained in usage and in some bakeries is used to a large extent, although the straight-dough method is said to afford a saving in time, labor, and overhead, and is less liable to error.

The essential procedure in the straight-dough method is generally along the following lines. Water is weighed out in proper quantity and adjusted to the correct temperature which is necessary for fermentation. A portion of the water is used to make a uniform culture with the yeast. In case powdered milk is used, another portion of water is utilized to get the milk solids in suspension. Then the milk solution is run into a dough mixer together with the salt, sugar, and malt extract (which has been previously dissolved and mixed in water), after which these ingredients are mixed together by a few revolutions of the mixer arms. Flour is next added up to one-half the final amount to be used and the various ingredients mixed again. Then the yeast solution and the remainder of the flour are added and the mixer is allowed to run for a short time. The shortening is next added and the mixing carried to completion. The dough mixer is usually water-jacketed to enable a close control of temperature during the entire mixing period, although cold air may be blown into the mixer to attain the same result. It is generally stated that the dough should come out of the mixer at a temperature between 76 and 79°F.

A sticky, weak dough may result from overmixing, owing to injury to the physical properties of the gluten. Such a procedure will be injurious to the texture, grain, and volume of the final loaf. Undermixing, on the other hand, produces a nonuniformity of ingredients and irregularities in the fermentation and conditioning of the dough.

After the dough is properly mixed, it is placed in lightly greased troughs to ferment and condition. This part of the process is usually carried out in a conditioning room in which two factors are of the utmost importance, namely, temperature and humidity. The optimum tempera-

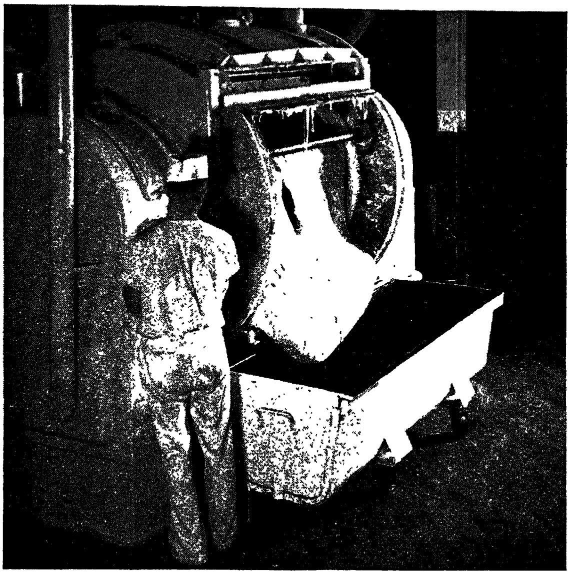


FIG. 50.—Emptying dough into fermentation troughs from mixer. (*Courtesy of General Mills.*)

ture for straight-dough fermentation is about 80°F. The relative humidity should be sufficiently high to prevent or limit the evaporation of moisture from the surface of the dough, as this tends to cause a superficial hardening or skin formation. In commercial operations the dough in the trough is folded and turned one or more times to provide a more uniform product.

After a satisfactory conditioning period, the dough is ready to be cut by machine or hand into the appropriate size for the pans. If the cutting is done by machine, scaling is necessary in order to insure against underweight and also to insure against losses by overweight. Cutting the dough leaves the sides open and allows some of the carbon dioxide gas in the dough to escape. The loaf is rounded or balled up by machine or hand. Rounding serves to put a protective film about the exterior of the dough, which tends to prevent losses of carbon dioxide.

Immediately following the rounding the dough is given an opportunity to rise and become lighter. A period of 10 to 15 minutes is generally sufficient if a compartment or cabinet free from drafts or temperature changes is used. Sometimes sliding trays, drawers, or moving belts are used for this purpose, in any of which cases dusting flour is used to prevent the loaves from sticking to the equipment.

When a moving belt is employed, the length of the belt and the speed of it are so regulated that the pieces of dough emerge from the chamber at the end of the proper time interval, at the place where they are to be moulded into loaves. This period of short rise is known as the short or intermediate proof.

The individual pieces of dough are next moulded and placed in lightly greased pans which should be of the correct size for the particular loaf in order to secure the best results. The seams of the loaves are placed downward in the pans. The pans are placed on racks, each with a capacity of many loaves, which may be rolled on wheels or conveyed by an overhead trolley to the room where the pan proofing is to take place. Since moulding causes a loss of much of the carbon dioxide from the dough, it is necessary for the loaves to rise to at least double their volume before baking in order to obtain a light bread.

The proofroom must be kept under accurate control, from the standpoint of both temperature and relative humidity. The temperature desirable is from 90 to 95°F. and the relative humidity is 80 to 85 per cent. In modern bakeries automatic temperature- and humidity-recording devices are used in order to keep an accurate record of conditions in the proofroom. Many proofrooms are also equipped with automatic-control devices to maintain these necessary conditions without the necessity of manual control. As a rule it takes from 30 to 60 minutes for the dough to rise sufficiently under such conditions.

The proofroom is a place where the loaf may be spoiled unless the utmost care is used. Underproofing results in a small loaf which will probably be heavy and soggy after baking. On the other hand, too long a period of proofing weakens the gluten and the loaf may become distorted or fall in the oven. Excessive temperatures, coupled with long proofing, favor the development of those types of bacteria always present in the flour, which can cause sourness and allied troubles. If the room is not properly constructed, the condensation of moisture on the ceiling may cause drops of water to fall on the loaves, with a resulting poor appearance of the finished bread. In moving the dough from the proofroom into the oven great care should be exercised to prevent the dough from falling or collapse.

After leaving the proofroom, the bread passes at once to the oven. Two main classes of ovens are in use, one in which the pans remain sta-

tionary and the other in which the pans are conducted by a conveyor system. There are many modifications of each. Gas, oil, coke, coal, or electricity may be used for fuel. The firebox itself is generally separated from the oven, but the heat is circulated over and around the oven as evenly as possible.

The temperature of the oven is generally maintained between 375 and 450°F., with an optimum temperature of about 400°F. Flash heat is undesirable because it tends to form a crust when the inside of the loaf may not be properly cooked. Under ordinary circumstances the temperature of the inside of the loaf rarely reaches above 212°F. (boiling temperature), when the outside of the loaf has reached the temperature of the oven, but these temperatures are usually sufficient. The high temperature used in baking causes the formation of the crust at the outer surface, where dextrinization of the starch takes place, and a golden brown color is brought about by the toasting effect or slight caramelization of the sugar present.

Immediately after the loaf enters the oven, it again expands to about double its original size. This expansion is due to several factors. The maximum evolution of carbon dioxide by the yeast goes on until a temperature of 140 to 150°F. is attained, after which the enzymes of the yeast are inactivated. Both the air and the carbon dioxide entrapped in the dough also expand, owing to the increased temperature. There is also a considerable quantity of carbon dioxide absorbed or dissolved in the dough which is gradually driven off by the rising temperatures, and this tends to lighten the dough. The swell in the bread is fixed, or the loaf "sets," owing to coagulation of the proteins, the loss of moisture, and the fixation of the starchy materials present.

The time necessary for proper baking depends largely on the size of the loaf and the temperature used. In general it may be said that 1 hour at a temperature of 428°F. will bake the bread well. The time required for baking is no problem with the modern oven which has automatic temperature control and is equipped with a moving endless belt which conveys the bread through the oven at a definite rate of speed and delivers it completely cooked at the other end. If changes in the baking time are necessary, the speed of the belt may be changed sufficiently to attain the desired results. Most of the more modern ovens are controlled within very narrow limits of temperature by thermostats which also have visible recording charts which enable very accurate control and knowledge of the temperature in the ovens. With such devices available, the spoilage from improper baking should be negligible.

The product from a large modern bakery is almost invariably wrapped in a special jacket for sanitary handling. If bread is wrapped just after it has been removed from the oven, *i.e.*, while still hot, there is consider-

able danger that it may become superficially mouldy or the inner portion may become ropy. Both these defects may be prevented by allowing a brief cooling period. One of the chief requirements for the growth of

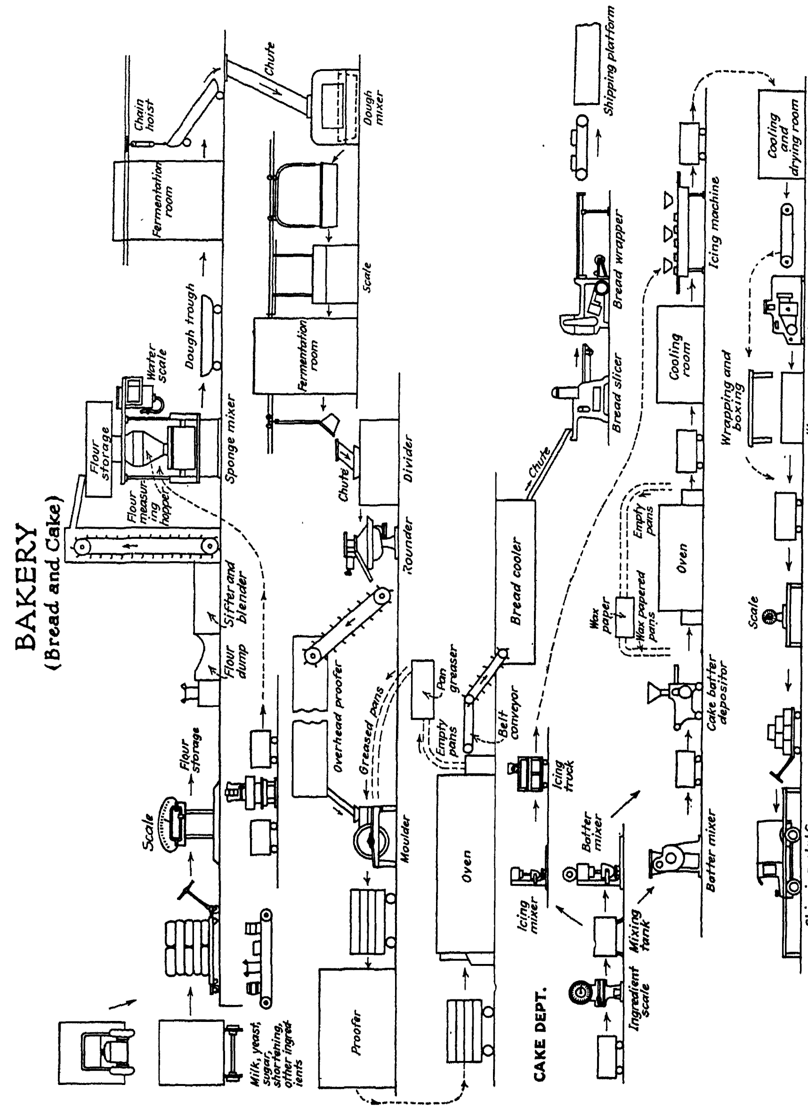


FIG. 51.—Flow chart of bakery operations. (*Courtesy of Food Industries.*)

moulds, besides having available food and oxygen, is the presence of moisture. A loaf wrapped too soon while steam or water vapor is still being expelled from it favors the development of a soft moist crust. The spores of moulds are practically ubiquitous and are likely to be found in

the air of bakeries; they are also sometimes on the paper wrappers used for bread. If such mold spores gain access to a loaf which has a soft moist crust, or a condensation of moisture occurs within, the conditions are favorable for the development of fungous growths. As an aid in combating this condition strict cleanliness of the bakery in all respects is necessary. Filtering and washing of the air is advantageous in keeping down the numbers of spores in the air. The best wrappers are now practically sterile and should be protected from dust-borne microorganisms as fully as possible, and stored before use in a clean, dry room. These facts explain why the bread itself should be allowed to cool until a dry surface is assured and until the temperature of the interior of the loaf is below 95°F. In many bakeries this cooling is done by a brief artificial refrigeration in order to reduce the time element necessary.

Ropy bread is caused by the growth of bacteria, particularly spore formers such as *Bacillus mesentericus*. The spores of these microorganisms are sometimes present in flour and in water or in certain other raw materials, but they are also liable to be present in dust and in the air, and, as they are relatively resistant to heat, may survive the baking process, particularly in the interior of the loaf. The name "rope" is applied to this trouble because the crumb of the infected bread, when squeezed between the fingers and then pulled out, produces strands of material which somewhat resemble long threads. The condition of ropiness is sometimes apparent by the development of an odor which is frequently described as resembling an overripe cantaloupe. Bread so infected is nauseating to the taste, is usually slightly discolored, and has a viscous crumb, particularly in the interior of the loaf. It is a serious trouble in the baking industry and precautions should be taken to avoid it. Such precautions would include:

1. General cleanliness in the bakery.
2. Avoidance of excessive temperature in fermentation and proof-rooms.
3. Elimination of excessive time period for raising the dough.
4. Thorough baking to avoid excess moisture in the loaf.
5. Rapid cooling to below 95°F.
6. Storing bread under conditions of low humidity.

As this organism grows best at neutral reaction, and as an acid condition of the bread is inhibitory to the causative bacteria, some bakers use small amounts of acid (sometimes vinegar) in the bread to combat this condition, particularly in warm weather.

Extremely rapid cooling of the bread after it leaves the oven has a tendency to cause cracks in the crust. A reasonable humidity must be maintained in order to prevent an excessive loss of moisture from the loaves. On the other hand, excessive humidity has its disadvantages.

It is wise to leave the bread in the oven room for a period of 15 to 20 minutes and then transfer it to the cooling room. In summer it may be necessary to cool the room and in cold weather some heat may be desirable.

As has been mentioned, artificial refrigeration is used in some of the more modern bakeries. This is sometimes in the form of a blast of chilled air through which the loaves pass while on a conveyor belt on their way from the oven room to the wrapping department. Under no circumstances, however, should the loaves be wrapped until the interior of the loaf has reached a temperature of 95°F. or below.

Bread may be judged in accordance with a number of properties, some of which are general, such as color, volume in respect to weight, and shape of the loaf. Some factors concern the crust and others the crumb, or interior of the loaf. The crust properties include taste, color, bloom, thickness, softness, and capability of digestion. Each of these factors is dependent in part on the quality and proportion of the original ingredients as well as the methods of production, including the fermentation processes, baking temperature, and similar factors.

The properties of the crumb which are of importance include color, grain, texture, and velvetiness, as well as the flavor and aroma, palatability, and digestibility.

The above qualities may vary considerably in different breads. The average large bakery may produce 20 or more different types of bread for various consumers each day. In order to have a uniform product it is necessary to standardize the ingredients as nearly as possible, control time, temperature, and humidity in the fermentation, and the time and temperature of baking. In some of the largest bakeries the timing is carried out with almost split-second precision and the temperatures of fermenting rooms and ovens controlled automatically to obtain the utmost in uniformity.

One of the greatest variables is the flour, and each shipment of new flour must be carefully tested before use in large-scale operations.

The following official definitions for bread are used in the United States.

Bread is the product made by baking a dough consisting of a leavened or unleavened mixture of ground grain and/or other edible farinaceous substance, with potable water, and with or without the addition of other edible substances.

White bread is the product, in the form of loaves or smaller units, obtained by baking a leavened and kneaded mixture of flour, water, salt, and yeast, with or without edible fat or oil, milk or a milk product, sugar and/or other fermentable carbohydrate substance. It may also contain diastatic and/or proteolytic ferments and such minute amounts of unobjectionable salts as serve solely as yeast nutrients.[1] The flour ingredient may include not more than 3 per cent of

[1] U. S. Dept. Agr. S.R.A.F.D. 2, Rev. 4. The propriety of the use of minute quantities of oxidizing agents as enzyme activators is reserved for future consideration and without prejudice.

other edible farinaceous substance. White bread contains, one hour or more after baking, not more than 38 per cent of moisture. The name "bread" unqualified is commonly understood to mean white bread.

Whole-wheat bread, entire-wheat bread, graham bread, is the product, in the form of loaves or smaller units, obtained by baking a leavened and kneaded mixture of whole-wheat flour, water, salt, and yeast, with or without edible fat or oil, milk or a milk product, sugar and/or other fermentable carbohydrate substance. It may also contain diastatic and/or proteolytic ferments, and such minute amounts of unobjectionable salts as serve solely as yeast nutrients. It contains, one hour or more after baking, not more than 38 per cent of moisture.

Milk bread is the product, in the form of loaves or smaller units, obtained by baking a leavened and kneaded mixture of flour, salt, yeast, and milk or its equivalent (milk solids and water in the proportions normal to milk); with or without edible fat or oil, sugar and/or other fermentable carbohydrate substance. It may also contain diastatic and/or proteolytic ferments, and such minute amounts of unobjectionable salts as serve solely as yeast nutrients. The flour ingredient may include not more than 3 per cent of other edible farinaceous substance. Milk bread contains, one hour or more after baking, not more than 38 per cent of moisture.

Extent of the Baking Industry

The 14,800 bakery establishments of the United States required the services of some 200,000 employees in 1933, and produced an output with a value of over 919 million dollars. In 1929, previous to the depression, the products had a value more than 50 per cent greater. From the standpoint of value of production, New York is the most important state, followed by Pennsylvania, Illinois, California, Massachusetts, New Jersey, and Michigan. Of these products, bread and rolls were the most valuable and made up 57 per cent of the value of all commercial baked products. During the same period biscuits, crackers and cookies amounted to about 15 per cent, soft cakes and loaf cakes to something over 10 per cent, doughnuts, crullers, and fried cakes to approximately 12 per cent, pies 0.4 per cent, and pastries and cream puffs less than 0.2 per cent of the total baked products in value.

Constituents in Bread Making Other than Flour

Yeast.—One of the most important constituents used in bread from the standpoint of the quality of the final product is the yeast. Yeast, technically called *Saccharomyces cerevisiae,* is a culture or aggregation of millions of small single-celled plants which have the characteristic ability of converting sugars mainly into carbon dioxide and ethyl alcohol. In some of the fermentation industries the alcohol is the main product and the carbon dioxide a by-product, or perhaps more frequently a waste product as the gas is not even collected. In the baking industry, however, the conditions are reversed because the baker is interested in the carbon dioxide which lightens and leavens his loaf and thereby makes it

palatable and appetizing. At the same time, the baker is usually not interested in the alcohol which is driven out of the bread to a large extent during the baking, although some attempts have been made in large bakeries to recover the alcohol found in the vapors from the ovens.

The special *Saccharomyces cerevisiae,* used as baker's yeast, are cultures or strains which have been found to have favorable fermentation characteristics when isolated and allowed to propagate under optimum conditions in as near pure-culture conditions as possible. They do not impart any objectionable tastes, but more likely improve the flavor of the bread. Brewer's yeast may be used, but the results obtained are less satisfactory than when a culture of baker's yeast, a modified culture of distiller's yeast, is used. The commercial yeast companies usually put their compressed yeast up in convenient 1-lb. packages which are stored at about 45°F. until just before they are to be used. The yeast should always be as fresh as possible.

It is essential that the yeast culture which is used should be vigorous, one that will produce considerable quantities of carbon dioxide in a short space of time and bring about a quick rising of the dough. The quantity of yeast used will also be a factor in the speed at which the fermentation goes on, and the temperature at which the dough is kept will also be of extreme importance. The more active the yeast fermentation, the less likelihood there will be of undesirable bacterial fermentations in the dough.

Yeasts utilize the monosaccharides, dextrose and fructose, directly, and can readily ferment maltose and sucrose after inversion. In order to obtain these sugars, they must secrete invertase and maltase, two enzymes which convert sucrose and maltose, respectively, into their constituent monosaccharides. Yeasts also secrete proteolytic enzymes which have a desirable action on the gluten of the flour.

Malt extract itself contains enzymes which are able to convert starch into dextrin and maltose or malt sugar, and therefore assists in providing foods for the yeast unless the extract has been previously heated to inactivate the enzymes. It also sweetens the dough and aids in the production of crust color, which is largely due to dextrins. Maltose may be obtained by the yeasts from the malt extract which is used to a considerable extent in making up the dough, or from a slight hydrolysis of starch during the early part of the process.

Sucrose, or saccharose (cane sugar), which forms the main sugar for the yeast to work on, is added to the dough for this purpose, as well as to sweeten the bread to the taste and improve the flavor. It is used to the extent of 1.5 to 4.0 per cent, based on the flour weight.

In addition to the use of malt extract which serves in part as a yeast food, certain other materials of a chemical nature may be added in small

quantities to the dough which act as yeast nutriments or stimulants and thus cause more rapid gas evolution by the yeasts. Chemicals for this purpose are used in relatively small quantities and may include certain phosphates, bromates, ammonium salts, per-acid salts, calcium salts, lactic acid, and similar yeast-growth accelerators. They are usually called "improvers" by the bakers.

The use of salt in bread serves a dual purpose, as it has a valuable part in the production of flavor in the bread and also has the property of controlling in part the fermentations which go on in the dough. A proper control of the salt concentration is believed to limit the utilization of sucrose, and by this method it is possible to have more unchanged sucrose available. The desirable brown color of the crust is improved by the caramelization of the remaining sucrose during baking. Salt is also said to impart strength and binding power to the gluten.

The use of shortening enhances the palatability of bread and also adds to the food value, keeping qualities, and appearance of the bread.

The shortening agents which may be used include butter, lard substitutes, such as hydrogenated vegetable oils, and beef stearin. Such materials reduce the normal toughness of bread or "shorten" it, tend to retain moisture, and impart a definite flavor to the product. If used in excess, these agents interfere with the yeast fermentation.

Water is a most important ingredient of bread and that used in bakeries should be of quality suitable for ordinary drinking purposes. A rather hard water is more desirable for bread-making purposes particularly if it contains those salts favorable to yeast development. Alkaline waters tend to affect gluten undesirably and thus should be avoided. It has been shown by Morison[1] that the use of chlorinated-water supplies is not likely to have deleterious effect on bread quality or the yeast fermentations necessary for the proper manufacture of bread.

Milk may be used in place of water and besides acting as a moistening agent, adds solids to the dough. In the larger bakeries milk concentrates, such as evaporated or powdered whole milk or skim milk, are sometimes used, thereby adding nutriment to the bread and enhancing its quality and value. Butter is seldom used because of its higher cost. Milk has the same general properties as shortening when used in bread with possibly more influence on the nutritional value and appearance. Milk is also said to increase the yield of bread.

BISCUIT "CRACKERS" AND COOKIES

One branch of the baking industry which has become of considerable importance is the baking of biscuit, commonly called "crackers," and of

[1] Morison, C. B., *Cereal Chem.*, **1**, 267, 1924.

cookies. At one time these operations were confined to making the sailor's "hard tack," pilot bread, Boston crackers, and similar products, while the home kitchens supplied ginger snaps, molasses cookies, sugar cookies, and the wide variety of similar products. These represent only a few examples of the infinite varieties of baked materials which are now produced commercially, and are so appetizing and attractive that many home cooks have ceased to be competitors in this field. The increased use of packaging materials of paper, parchment, cellulose films, metal containers, and other convenient small-unit packages for such products, has facilitated their merchandising, and has particularly popularized these types of manufactured foods.

The basic ingredient of most crackers and cookies is flour and the flours from winter wheats are considered more desirable than the spring wheats which are used for bread. For the making of dough for soda crackers and plain biscuits a sponge is made which goes through a yeast fermentation. Others more closely resemble cake batter, which may use chemical leavening agents instead of yeast. The baking in some of the larger biscuit plants is carried out in huge automatic ovens which are continuous in operation and may bake tons of products in a day.

The fancy products may have either as ingredients or as icings such materials as nuts, coconut meats, marshmallow, jelly, chocolate, pineapple, cherries, and candies, which add to the mechanical operations involved. The icings are not added until the foundation has been baked but may require some slight heat treatment to finish the product. The use of conveyor systems of belts, racks, and trays on overhead trolleys and similar devices facilitate these operations. The pieces which require enrobement with chocolate often are handled in separate air-conditioned rooms with refrigeration and controlled humidity.

Much effort has been directed toward the development of packages which will keep these products in optimum condition until such time as they may be opened by the consumer. In addition to being dirt- and verminproof, there is a distinct need for preventing the access of moisture and in some cases, of light, as light may be a causative factor in promoting rancidity of the shortening used and thus cause off-flavors.

Since the advent of vitamin interest and the knowledge that ultraviolet light may confer antirachitic potency to food products, some types of crackers have been irradiated. Experiments by Read and Bailey have shown that the use of ultraviolet light on soda crackers may effect an antirachitic activation without causing rancidity, provided the proper shortening is used.[1]

[1] *Cereal Chem.*, vol. 10, No. 2, 1933.

BAKING POWDER AND SIMILAR LEAVENING AGENTS

Other means besides yeast fermentation may be used in order to accomplish leavening. In earlier days bread was frequently made by spontaneous fermentations which resulted from allowing flour or meal mixed with water or milk and a little salt to stand for a number of hours in a warm place. Under these conditions a bacterial fermentation resulted (or possibly a mixed bacterial and yeast fermentation), gas was produced by action of the organisms or their enzymes on carbohydrates, and the fermenting mixture was then added to the other ingredients of bread, subjected to further fermentation and eventually baked. The results obtained by such methods are dependent on the types of bacteria present and able to predominate under those conditions. Bacterial examination of flour shows the fairly constant presence of such gas-forming types. Needless to say, the product is likely at times to be unsatisfactory and at any rate far from uniform in quality. A so-called "salt-rising" yeast culture may be obtained commercially which is a bacterial culture suitable for use as a leavening agent but, as with true baker's yeast a certain amount of time is needed to accomplish the leavening.

There are other methods of leavening, principally by the use of chemical agents, which may cause the evolution of gas in dough masses in a relatively short time. In the home it is frequently done by using sour milk as one of the dough ingredients and adding sodium bicarbonate, baking soda, which interacts with the subsequent development of carbon dioxide. As this is usually done by guess, the amount of soda used may be too great and the resulting product an inferior one.

Numerous chemical compounds are now available for this purpose, generally under the name of baking powders, and have obtained wide usage. Among the earliest used in this country were mixtures of cream of tartar, soda, and starch, the last acting merely as a stabilizing ingredient. Cream of tartar is obtained from the wine industry where argols, the crystalline precipitates from grape juice, are formed during storage or fermentation. On purification and recrystallization such deposits yield the cream of tartar of commerce, which chemically is potassium bitartrate or potassium hydrogen tartrate.

Tartaric acid has a similar origin, as it may be derived from either cream of tartar or from calcium tartrate by treatment with sulphuric acid. Calcium tartrate also comes from grapes, particularly from the dark precipitate called lees found in wine barrels and vats. Another early preparation was composed of two ingredients, monocalcium phosphate and soda, which were packed separately but in a common package, with direc-

tions such that the former could be used in a ratio of 2 parts to each portion of soda when added to dough for baking purposes.

The baking powders most commonly used come in three general classes, according to Bailey[1] depending on their acid-reacting ingredients.

1. Those composed of cream of tartar, which may also have tartaric acid.
2. Those composed of calcium acid phosphate or sodium acid pyrophosphate.
3. Those composed of sodium aluminum sulphate and calcium phosphate.

In 1928 the U. S. Department of Agriculture set up the following standards for baking powders.

> Baking powder is the leavening agent produced by the mixture of an acid-reacting material and sodium bicarbonate, with or without starch or flour. It yields not less than 12 per cent of available carbon dioxide.
>
> The acid-reacting materials in baking powder are:
>
> 1. Tartaric acid or its acid salts.
> 2. Acid salts of phosphoric acid.
> 3. Compounds of aluminum.
> 4. Any combination in substantial proportions of the foregoing.
>
> Other substances may be used, provided they are harmless and plainly stated on the label.[2]

The powders in the first group liberate all their evolved carbon dioxide at ordinary temperatures, while the phosphate types do not free all their gas until the dough reaches the oven. It is thus apparent that the proportion and the type of various ingredients in a powder determine when the gas will be evolved. Bakeries generally prefer those which require oven temperatures before all the gas is evolved.

In recent years the annual production of baking powders in the United States has sometimes exceeded 150 million pounds and the exports 5 million pounds, the most important importing country being British South Africa.

The following reactions indicate the chemical changes which take place when some of the more common components of baking powders are used as a source of carbon dioxide for leavening purposes:

$$H_2C_4H_4O_6 + 2NaHCO_3 \rightarrow 2CO_2 + Na_2C_4H_4O_6 + 2H_2O$$

$$CaH_4(PO_4)_2 \cdot H_2O + 2NaHCO_3 \rightarrow 2CO_2 + CaNa_2H_2(PO_4)_2 \cdot H_2O + 2H_2O$$

[1] Bailey, L. H., Development and Use of Baking Powder and Baking Chemicals, *U. S. Dept. Agr. Circ.* 138, 1930.

[2] U. S. Dept. Agr., Food, Drug and Insecticide Administration. S.R.A.F.D. 2, Rev. 1, 1928.

$$NaH_2PO_4 + NaHCO_3 \rightarrow CO_2 + Na_2HPO_4 + H_2O$$
$$Na_2H_2P_2O_7 + 2NaHCO_3 \rightarrow 2CO_2 + 2Na_2HPO_4 + H_2O$$
$$Na_2SO_4 \cdot Al_2(SO_4)_3 + 6NaHCO_3 \rightarrow 6CO_2 + 2Al(OH)_3 + 4Na_2SO_4$$

"BREAKFAST FOODS" AND OTHER CEREAL PREPARATIONS

While bread and its other closely related bakery products constitute the most important food products derived from grain, there is another group of foods having the same origin which in recent decades has made great strides in development and must be classed among the important manufactured foods. These include the cereal preparations, and especially the so-called breakfast foods and prepared flours and flour mixtures used for a variety of products. The oatmeal which was for many years the principal type of product of this class probably originated in Scotland, and is now but one of the many grain preparations which are so used. Oats, corn, wheat, barley, and rice, and possibly other grains are now subjected to a variety of treatments which yield appetizing and reasonably nutritious foods. These may be mixed with a certain proportion of other ingredients such as malt sugar or finely ground bran, and subjected to precooking treatments which render them "ready to serve" or easily and quickly prepared in the home.

Cereal preparations including breakfast foods, prepared flour, coffee substitutes, and similar preparations made from wheat, oats, corn, and other grains, are produced annually to the value of over 100 million dollars. Michigan, Iowa, Illinois, and New York are the most important producing states.

The past two decades have given evidence of a decided change in trend of American dietary habits concerning cereal preparations for breakfast or other special purposes. The greater proportion of such products are now packaged in small consumer units and many are precooked or otherwise treated in factories. This is in decided contrast to the earlier use of cereal products such as wheat, corn, oats, and rice which were sold in bulk, either whole or ground, for final preparation in the household.

The cooking treatment varies in method and extent. Some are sufficiently cooked to render further heating before consumption unnecessary. Others are only partially prepared for ingestion and must be subjected to cooking, usually in boiling water, previous to utilization. As most products of this nature are relatively high in starch content, the pretreatment may hydrolyze the starches to dextrins if sufficiently extensive. The main advantage of such treatments is the saving in time in household preparation, and the variety reduces the monotony of use of a single product day after day. The factory products may be of an infinite

variety of forms, flavors, and even colors, as a result of heating. In comparison with the early types of coarse meals these new products are considered more desirable by some consumers, although the nutritive value is seldom commensurate with the much greater cost, based on the weight of available food material.[1]

MACARONI

Macaroni, spaghetti and similar products are important foods in this country where some 500 million pounds constitute our annual production, although they are more widely used elsewhere. Both China and Japan claim that such products originated in their lands and indications tend to the conclusion that somewhat similar pastes and noodles made from rice flour were known in Asia several thousand years before the Christian era.

According to Bitting, such pastes were rolled out thin, cut into strips and noodles, which were then dried. Such products became known in Germany during the Mongol invasions and later were adopted by the Italians, who grew a high-protein variety of wheat admirably suited as a raw material in place of rice flour and called the new product "macaroni." The first establishment of this nature in the United States was a paste factory started in 1885. The modern products which require hydraulic presses in order to make cylinders, elbows, shells, stars, and other odd shapes were first manufactured here in 1894 since which time the popularity of these products has increased greatly.

"Macaroni is the shaped and dried doughs prepared by adding water to one or more of the following: semolina, farina, wheat flour. It may contain added salt. The moisture content must not exceed 13 per cent."[2] There are many kinds of macaroni products, differing in size, shape, and appearance.

In 1929 the manufacture of macaroni, spaghetti, vermicelli, and noodles amounted to 553 million pounds with a value of over 46 million dollars in this country. These products were formerly imported in considerable quantities but during the period from 1927–1932 the imports were less than 1 per cent of the amount produced in this country. In 1932 the United States exported over 3 million pounds of macaroni.

Macaroni products are manufactured primarily from semolina and farina milled from durum and other hard wheats which are flinty and translucent. Semolina is a coarsely ground and carefully purified milling product or middlings of durum wheat. Farina is similar, except that it is

[1] For a description of some of the more common prepared breakfast foods and their processing, the reader is referred to Food Industries, by H. F. Vulté and S. B. Vanderbilt, 1923.

[2] U. S. Dept. Agr. S.R.A.F.D. 2, Rev. 2, May, 1933.

obtained from hard wheats other than durum. Both are obtained from wheat endosperm and are of a particle size such that they will be retained on 10XX silk bolting cloth. It is essential that there be a minimum of bran present because macaroni products tend to break at the point where bran particles are present. The best grade of semolina is essential in making long-cut macaroni products.

A dough is generally made of the various ingredients, kneaded for a short interval of time, then rolled in sheets or transferred to the press

FIG. 52.—Macaroni dryer. (*Courtesy of Beech-Nut Packing Company.*)

which is kept at a temperature slightly above 100°F. in order to keep the dough in a plastic condition. The press, usually a vertical machine for the longer types of macaroni, has a die or mould at the bottom through which the dough is forced under a pressure of 2,000 to 4,000 lb. per square inch. The construction of the apertures in the die determines the shape and diameter of the product, as well as the size of the hole.

Macaroni was usually dried in the open air in Italy where these products have a much greater per capita consumption than is the case in the United States. Manufacturers in this country, also the more modern European plants, avoid the contamination of exposure in the open air by carrying out the drying process in specially constructed rooms equipped

with air-conditioning and filtration apparatus. These facilities enable accurate control of temperature and humidity which are essential to the production of a product of highest quality. Trays are used for drying the short-cut products, while racks and sticks support the long-cut types which are hung over the sticks.

The drying process is rather a slow one and may require several days, depending on the particular product. When completed, the long-cut macaroni is cut into appropriate lengths and much of it packaged. If the moisture content is sufficiently low (13 per cent), macaroni may be kept for long periods of time without difficulty, provided the storehouse is cool and the humidity low.

High-quality macaroni should be hard, brittle, elastic, and of rich amber color. It should be capable of bending somewhat if in long pieces. The surface should not be perfectly smooth and some very small bran specks are likely to be present. On boiling for 10 minutes the size should be doubled, yet its tubular shape and firmness retained. The use of artificial coloring is prohibited by the Federal Food and Drugs Laws. Special care is required in manufacture, and in preventing the infestation by very small weevils' eggs which are sometimes found in the flour from which these products are made.[1]

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CHAPTER XIV

CANNING

BY DR. A. W. BITTING[1]

No technologic advance has exerted greater influence on the food habits of the civilized world than the development of heat treatment and the use of hermetically sealed containers for the preservation of foods. As a result of the earlier work in this field, supplemented by great improvements in technique, in machinery and apparatus, and in knowledge, it is now possible to enjoy the choicest foods, at any time regardless of season, which have been harvested from all corners of the earth under the most favorable conditions of quality so that their flavor and texture approach perfection. The desirability of such available foods, preserved in a manner which maintains their optimum qualities, is further emphasized by their nutritive values which are practically equivalent to those of the fresh material. In addition there are the factors of economy, by reason of the fact that such foods are packed during those periods when the crops are in season and therefore at their lower price levels, and the very important consideration of utility because many canned foods are available for table use without the drudgery of cleaning and preparation needed if the fresh material is purchased as such.

The art, or more properly the science, of canning is deeply indebted to Nicholas Appert because his early efforts made him the most prominent worker and enthusiast in this field.[2] Although the process of food preservation in hermetically sealed containers could well be called Appertizing in honor of his industry, perseverance and genius, this term has never become common. A vast monument to the founder of this important food industry is constructed each year, however, if one considers the billions

[1] The authors are indebted to Dr. Bitting for the text of this chapter. His vast knowledge of the subject and his long experience in investigating both the scientific and the practical aspects of the great canning industry in America give assurance of its authoritative character. No other man can write with such mastery of this branch of food technology.

[2] For an extensive treatise on the subject the reader is referred to A Complete Course in Canning, published by *The Canning Trade*, Baltimore, Maryland. This book, covering both general and specific information regarding the canning of all the common foods, has served as a basis for a part of the material of the present chapter. The courtesy of the Editor of *The Canning Trade* in this respect is hereby acknowledged.

of cases of canned and heat-treated foods which are produced and consumed annually.

The work of Appert to find a better means of food preservation was inaugurated in 1795, and it was only after a period covering seven or eight years of arduous experimentation that he discovered how success was due to the combination of proper heating of the food substances in the container and tight sealing, or that he had sufficient confidence in the methods used to offer a preserved product to the public. The method consisted in placing foods in bottles, corking them tightly, and heating them in water baths for varying periods of time, depending on the substance. The result was preservation of the food as long as the seal was unbroken and in a form which could be conveniently stored or transported yet was ready for use at any time.

The method which Appert proposed was so revolutionary in character that the French government appointed Gay-Lussac, an eminent scientist of that day, to investigate why foods kept under the treatment given. The theory advanced by Gay-Lussac, although subsequently proved as incorrect, is sufficiently interesting to quote briefly, because it exemplifies the ideas which were prevalent during the first half of the nineteenth century. "The vegetable or animal substances, by their contact with air promptly acquire a disposition to putrefaction and to fermentation, but in exposing them to a temperature of boiling water in well-closed vessels, the oxygen absorbed produces a new combination which is not adapted to excite fermentation or putrefaction, but which becomes hardened by heat, in the same manner as albumin." This report of Gay-Lussac transmitted in 1810 was later elaborated in other reports in which he treated putrefaction as a series of oxidation changes in complex compounds in reducing them to their simpler elements.

Appert's own theory was that "The action of heat destroys altogether, or at least neutralizes, all the ferments which in the ordinary course of nature, produce modifications which, in changing the constituent parts of the animal and vegetable substances, alter the qualities."[1] This theory more nearly approaches the true situation than that of Gay-Lussac, but for about half a century the teachings of Gay-Lussac, elaborated, by Liebig, were generally accepted. It remained for Pasteur, in 1860, to disprove the older theories and place the problems of food preservation on a sound scientific basis.

Another worker connected with the early days of the canning industry was Thomas Saddington in England, who presented a method somewhat

[1] The reader is referred to an interesting translation of Appert's original book which appeared in 1810, The Art of Preserving Animal and Vegetable Substances for Many Years, which was translated and published by K. G. Bitting, Chicago, Illinois, in 1920. [The Authors.]

TABLE 97.—CANNED PRODUCTS, BY KIND, QUANTITY, AND VALUE BY STATES, 1931

Product and state	Quantity, No. cases	Value
Canned fruits:		
Apples, total	2,066,956	$ 3,321,767
Maine	23,560	$ 46,655
Michigan	43,879	71,794
New York	190,010	274,626
Oregon	183,003	307,197
Pennsylvania	349,724	542,073
Virginia	284,851	514,442
Washington	846,757	1,310,651
Other states	145,172	254,329
Raspberries, black, total	247,925	762,316
Michigan	103,938	$ 321,506
New York	57,195	171,974
Oregon	37,776	133,195
Other states	49,016	135,641
Raspberries, red, total	529,207	1,939,846
Michigan	6,544	$ 27,063
New York	165,905	426,343
Oregon	120,234	391,417
Washington	235,683	1,091,414
Other states	841	3,609
Peaches, total	8,616,647	22,639,588
California	8,463,178	$22,317,711
Georgia	63,534	93,590
Michigan	31,521	75,237
New York	16,483	82,078
Utah	5,300	8,793
Washington	1,438	3,023
Other states	35,193	59,156
Pears, total	3,917,832	12,123,971
California	1,877,313	$ 5,747,488
Illinois	1,415	4,755
Maryland	10,210	22,516
New York	57,375	175,145
Oregon	816,683	2,358,764
Washington	1,067,637	3,562,262
Other states	87,199	253,041

TABLE 97.—CANNED PRODUCTS, BY KIND, QUANTITY, AND VALUE BY STATES, 1931.
(*Continued*)

Product and state	Quantity, No. cases	Value
Canned vegetables:		
Asparagus, total	1,878,006	$10,392,195
California	1,736,348	9,747,038
Illinois	35,620	199,770
Michigan	18,494	49,338
New York	11,050	32,529
Other States	76,494	363,520
Beans, with pork, with sauce, and baked, total	11,730,701	23,309,674
Indiana	3,020,271	$ 3,755,460
Maine	114,912	284,935
Maryland	726,742	970,293
Michigan	332,713	483,072
New York	1,083,218	1,214,374
Other states	6,452,845	16,601,540
Corn, total	19,376,512	31,492,289
Delaware	157,102	$ 224,174
Illinois	3,626,441	6,956,787
Indiana	2,298,309	3,293,372
Iowa	3,140,046	4,745,712
Maine	1,231,514	2,092,707
Maryland	1,970,184	2,790,808
Minnesota	1,987,751	3,605,945
Nebraska	229,976	367,929
Peas, total	13,253,040	28,938,835
Delaware	260,417	$ 463,140
Illinois	939,099	2,234,504
Indiana	755,279	1,252,184
Maryland	1,244,547	2,102,455
Michigan	427,007	998,267
Minnesota	623,000	1,506,102
New York	1,718,150	4,566,163
Ohio	420,561	844,679

TABLE 97.—CANNED PRODUCTS, BY KIND, QUANTITY, AND VALUE BY STATES, 1931.—(*Continued*)

Product and state	Quantity, No. cases	Value
Canned vegetables.—(*Continued*):		
Spinach, total	1,773,966	$ 3,863,294
Arkansas	7,363	12,599
California	1,313,105	3,063,775
Iowa	9,135	17,640
Maryland	194,358	321,626
New York	117,303	220,680
Ohio	16,886	34,211
Other states	115,816	192,763
Tomatoes, total	13,893,596	21,694,102
Arkansas	998,360	1,309,293
California	1,095,801	2,187,214
Colorado	223,518	440,574
Delaware	498,352	762,764
Illinois	376,240	563,702
Indiana	1,867,750	2,938,878
Iowa	317,596	515,418
Kentucky	258,351	346,184
Tomato juice, total	3,476,244	6,211,595
Arkansas	2,324	2,888
California	411,705	1,011,799
Indiana	1,255,008	1,630,564
Iowa	136,584	187,470
New York	168,113	328,680
Ohio	23,212	40,363
Oregon	873	2,014
Utah	27,877	72,725
Other states	1,450,548	2,935,092
Tomato pulp, total	1,479,235	1,724,037
California	26,547	33,206
Illinois	20,563	22,676
Indiana	579,704	846,828
New York	106,885	121,249
Ohio	67,305	98,891
Utah	37,654	44,309
Other states	640,577	556,878

similar to that of Appert in 1807, although he did not claim to be the inventor. Peter Durand was granted an English patent in 1810 for a method of "preserving animal, vegetable, and other foods," also for containers, covering "vessels made of glass, pottery, tin, or any metal or fit materials." Durand has been called the "Father of the Tin Can," although the Dutch were said to have used crude canisters or cans previous to that time.

The earliest metal containers were difficult to close and one of the earliest improvements consisted of providing a vent hole in the cover, which was the invention of Angelbert in 1823. This enabled the cans and their contents to be boiled in a water bath with the cover attached, after which the vent could be closed with solder.

Thomas Kensett was the first person to obtain a patent on the process of canning and containers in the United States in 1825. Previous to this time canned foods were being packed in France, England, Scotland, Ireland, Germany, and this country. One of the earliest packers of foods in America was William Underwood, who in 1820 started an organization in Boston which has continued in the food industries for over a century and is still maintained under the guidance of the Underwood family.

Up to 1839 the general methods of processing were to immerse the filled food containers in boiling water. It had been suggested by Fastier that by using salt or sugar in the bath higher temperatures would result in driving off more oxygen, in line with the theory of Gay-Lussac and thus better keeping qualities would result. The method was not generally adopted until about 1850 and the theory advanced by Fastier was later discredited. Calcium chloride was the salt used to increase the boiling point. In 1851 Chevalier Appert perfected an invention which made such baths unnecessary. He perfected a manometer and temperature guage which could control the use of hot water and steam under pressure, a method which had previously been both uncertain and dangerous, and thereby opened the possibilities of accurate high-temperature processing. This invention proved to be a great boon to the industry and an improvement of great importance.

Between 1810 and 1850 many attempts were made to originate other methods of preserving foods. A number of these methods were based on theories involving the exclusion of air. Several involved the use of hot liquids to fill the air spaces between solid materials in the cans. Others included mechanical means of evacuation of the air. Unless these methods included the use of heat treatment and tight sealing, they were generally failures, but it required the work of Pasteur to demonstrate the cause of such failures.

The work of Pasteur in the allied fields of biology and chemistry has been an outstanding example of scientific experiment and laid the corner stone for much of the fundamental knowledge since that time, not only in biology but also in the medical sciences. His researches have not only paved the way for advances in many phases of science but also brought out the fallacies of the theories advanced by Guy-Lussac and Liebig regarding the nature of decomposition. His life should be an inspiration to all interested in a career of research and to such, the book, The Life of Pasteur, by Vallery-Radot, is recommended as a valuable reference.

Pasteur demonstrated a number of facts which have been of inestimable value in the progress of food preservation. Eventually they were accepted by his contemporaries, although not without strenuous opposition.

First, that a nutrient medium will remain unchanged if sufficiently heated in a closed vessel.

Second, that the exclusion of air or oxygen was not necessary as the medium might be protected from external influences by only a cotton plug.

Third, that spoilage occurred as soon as the cotton plug was removed and dust or microorganisms were allowed to fall into or upon the medium.

Fourth, that alcoholic fermentation was due to yeast developing in a sugar solution.

Fifth, that putrefaction was not due to oxygen in the air acting upon a substance, but due to the presence of microscopic organisms.

These conclusions are the basis of our knowledge concerning the preservation of foods today. The many improvements which have been made in the methods of canning since the time of Appert have produced better containers, more efficient heat treatment, and developed technique for the conservation of foods of numberless kinds, but the fundamentals of heat treatment to kill the microorganisms which may cause spoilage or disease and tight sealing to prevent the entrance of other microorganisms are essentially the same as outlined by Pasteur.

APPLICATION OF BACTERIOLOGY TO CANNING

The earliest published record of the application of bacteriology to canning is that by Prof. H. L. Russell, in 1895, just a hundred years after Appert began his notable experiments. The pea packers in Wisconsin were having losses from swells and were unable to overcome them through the empirical methods then in use. They were processing peas at 230°F. from 10 to 12 minutes. Prof. Russell determined that the swelling and odor were due to bacteriological action and after a few trials recommended

that the process be increased to 242°F. and continued for 15 minutes. The remedy was effective. His brief report, "Gaseous Fermentation in the Canning Industry," was published in the annual report of that experiment station.

Coincident with the foregoing work was that of Prof. S. C. Prescott and Mr. W. Lyman Underwood who began an investigation of canning processes and presented their first paper, "Micro-organisms and Sterilizing Processes in the Canning Industries," in October of 1896. These two workers continued their investigations over a number of years and presented papers on "Sour Corn," "The Cause and Prevention of Sour Corn," "Bacteria in Canned Foods," and "Souring of Peas" before the canners' conventions. They described the microorganisms causing losses, determined the temperature needed for their destruction, and the rate of of heat penetration in a can. Their series of papers had a potent influence upon the canners in causing them to accept the new science as the proper means of solving some of their problems rather than relying upon the secrets of the old-time processor.

Another pioneer investigator was Andrew MacPhail in Canada. He worked upon "The Cause of Blackening in Canned Lobsters," employing both bacteriological and chemical methods. He determined that the blackening was due to the formation of iron sulphide as a result of the action of the food material upon the container.

Harding and Nicholson of the New York Agricultural Experiment Station studied pea canning and published a bulletin entitled "A Swelling of Canned Peas Accompanied by a Malodorous Decomposition," in 1903. They described the organisms attending this form of spoilage and determined a process which would prevent it.

E. W. Duckwall started the first commercial laboratory for the study of canners' problems in 1902. He published "Canning and Preserving with Bacteriological Technique" in 1905.

Dr. G. H. McBryde of the Bureau of Animal Industry published a paper upon "A Study of Methods of Canning Meats with Reference to the Proper Disposal of Defective Cans" in 1907, and another on "Commercial Methods of Canning Meats" in 1911. These are among the few papers upon meat canning and the information is very general.

In 1913, Bronson Barlow prepared a thesis on "Spoilage of Corn at High Temperatures" which stressed the importance of the thermophilic forms of bacteria in canned foods. During the same year Paul S. Burgess contributed a study upon "Flat Soured Canned Corn and Pumpkin, together with Length of Time Required for Complete Sterilization."

The Bureau of Chemistry of the U. S. Department of Agriculture began the study of commercial canning practices in 1906. The first work was largely to obtain information for the proper enforcement of the Food

and Drugs Act. A laboratory was equipped for research work in San Francisco in 1912 which for a time engaged in work of this nature. Other laboratories were established by the American Can Co. and the National Canners' Association which have both grown markedly since that time and are still in operation. In 1917 the latter organization inaugurated an extensive study in connection with Harvard University on food poisoning. Later work on this same subject was undertaken at Leland Stanford University and the University of California in 1919 and 1920. In 1919 a laboratory was established by the Glass Container Association for the purpose of research on products packed in glass. Many institutions of learning and private research laboratories have been engaged in the problems of food preservation, as is also the case in numerous Federal and state research laboratories and experiment stations.

There are certain considerations which must be recognized in the canning of all fresh-food materials. It is essential that food materials be canned as soon as possible after they have been harvested. Definite and progressive changes of a chemical nature occur owing to enzymes in the product and microorganisms naturally present on the material. The longer the period of time required from the field to the factory, the greater the changes. Thus it is necessary to have the time element reduced to a minimum, which may be done *first*, by having the cannery near the source of supply; *second*, by expediting the shipment of the raw material; *third*, by controlling the harvesting so that it may coincide with the rate at which the cannery organization is capable of using the supply. If the factory site is not selected so that the finest raw material is near at hand, it is likely to be a serious handicap to the packing of high-quality products.

An adequate supply of water of unquestioned purity is another primary requirement for any food-processing plant. Water in vast quantities is necessary for the maintenance of sanitary conditions in a cannery, and the washing operations for fruit and vegetables often require many gallons of water for the cleaning of the raw material used in one can of the furnished product. Water is also needed for the making of sirups, for the production of steam, for cooling the product, and for the manifold other uses of water in any establishment. In addition to being pure from a health standpoint, the water must be of a chemical quality that will not be objectionable in view of its uses. The physical characteristics of canned foods and their flavors may be adversely affected by the use of improper water, which may be due to excessive hardness, mineral content, or objectionable organic materials in a water supply.[1] The quality of water used for the boiler plant is also of considerable importance. In

[1] For discussion concerning characteristics of potable water supplies see Air, Water, and Food, by Woodman and Norton, and Elements of Water Bacteriology, by Prescott and Winslow.

many canning plants water is also necessary in conveying waste materials from the factory into the waste-disposal system.

If no sewer system is available, adequate facilities for the disposal of all wastes must be maintained to prevent the development of nuisances and sanitary hazards, which are likely to be not only objectionable but sometimes dangerous.

The layout of any given cannery is dependent on many factors, which include the volume of materials packed, the type of foods packed, the permanence of the packing operations, and similar considerations which make each establishment an individual problem. There are certain requirements common to all, however. No establishment should be allowed which cannot be cleaned thoroughly and does not have adequate lighting. Cleaning is facilitated by having tight floors which are laid on a slope so that drains may be placed at intervals to remove water used in flushing the floors. Interior surfaces, such as walls, posts, ceilings, etc., should have smooth surfaces such that they can be readily cleaned. Proper lighting assures the operators being able to see dirt when it accumulates or prevents its accumulation. It also aids in the efficiency of grading products and tends to prevent accidents.

A necessary part of every modern factory is the installation of permanent cleaning equipment, water and steam lines with openings, so that tables, machines, vessels, floors, etc., may be cleaned on schedule and whenever needed. Air lines are desirable though not essential. Water is the first consideration and should be used generously, preferably under a pressure of about 40 lb. to the square inch. A weak pressure only makes a surface wet and, to the inexperienced, apparently clean, but too often is ineffective. High pressure will save much labor and scrubbing on tables and floors and will reach inaccessible places. The use of brushes is necessary at intervals, though the amount of that kind of work can be reduced where pressure is available. Steam is needed about machinery in particular and in cabinets for sterilizing pans and like equipment. The floors need to be pitched with reference to the lines of machines and tables and given a slope of 1 in. to every 10 ft. if of wood and 1¼ in. if of cement so that all water will drain away quickly. A lesser pitch will hold the water for several minutes and a greater pitch is fraught with danger to employees from slipping. There can be no excuse for an unclean or wet floor. Material of any kind upon the floor and a sloppy condition are conducive to bad habits on the part of employees.

The use of disinfectants about a factory to take the place of scrubbing and water is not to be recommended. The best one and the one to which least objection can be made is hypochlorite of soda. It may be purchased or made electrolytically by decomposing a solution of common salt, $NaCl$, in an electric cell. It may also be made by passing chlorine gas through

solutions of alkalies. This hypochlorite solution is inexpensive, may be used effectively in high dilution (0.4 per cent solution is commonly used), and is a good cleaning agent for enamel and porcelain surfaces. It may be sprayed on walls, ceilings, benches, and floors but should be preceded by thorough washing and preferably followed by a water rinse. This same agent is an effective spray for lug boxes, crates, and other containers for raw materials, as it cuts down the bacterial and mold infections which serve as inoculating media for all foods transported in the same.[1]

The equipment used in a canning plant is dependent on what foods are being packed, the volume of production, and to a certain extent on the finances of the owners. The period of use when a cannery may be able to operate any given equipment in one season is also a determining factor because many packing seasons in a given region last only a few weeks. Some equipment may be useful in the handling of a number of foods packed in the same plant, while other types might be essential for but one food, so the choice of equipment varies widely and depends on the decision of those in control.

The fruits in general require relatively simple equipment such as washers, graders for size, trimming tables, and fillers. Peaches require lye peelers and pineapples require special equipment. Corn, peas, string beans, and pimentos each have requirements for equipment which is not well adapted for other foods. Spinach is best handled through a washer and blancher built for the purpose, though that is not strictly essential. Asparagus requires only some minor devices for cutting the stalks to lengths and, by custom, the use of bamboo baskets in which to do the blanching. The tomato is handled most economically on an equipment which insures thorough washing followed by steaming to loosen the skin and then chilling to prevent softening. The work can be done with nothing more than a tank of hot water for scalding, though this is not advisable. If pulp products are made, then a pulper and evaporator are essential, and a finisher is a highly desirable accessory. Pumpkin requires steaming to soften the tissues and then pulping. Beets, carrots, sweet potatoes, and potatoes need no special apparatus other than grader, and cabbage, cauliflower, and celery do not even require that as an aid. Dry beans, red kidney beans, and hominy necessitate soaking facilities.

Regardless of the type of equipment used, it is of paramount importance that the sequence of various operations and the capacity of the various apparatus needed be so planned that there will be a minimum of delay in the flow of raw material to the stage of the finished processed product. Without a balance of proper equipment and coordination in

[1] See Meat through the Microscope, by C. R. Moulton, for a discussion of other uses of sodium hypochlorite in food establishments.

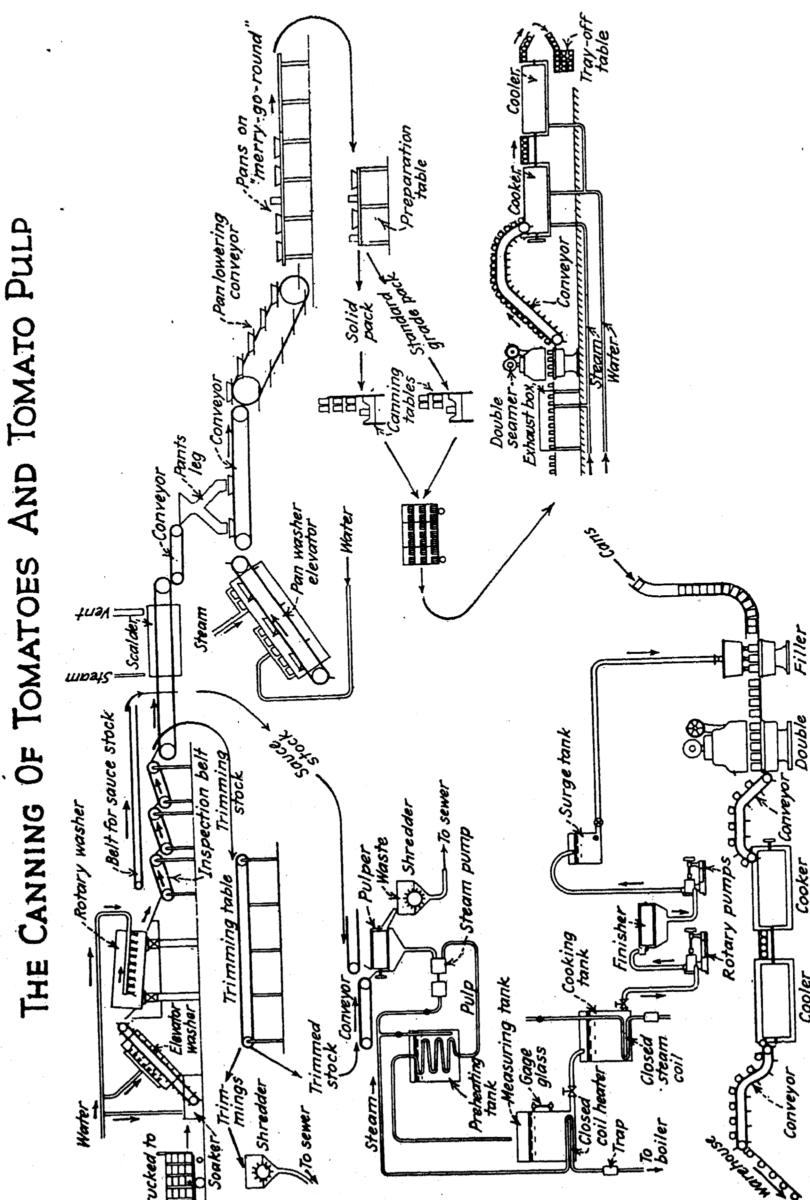

FIG. 53.—Flow chart of tomato-canning operations. (Courtesy of Food Industries.)

its use there are bound to be interruptions which result in lowered production and inferior quality of product.

The equipment common to the majority of fruit- and vegetable-canning plants include preparation tables, the distributing system for the products both before and after filling the cans, and for the delivery of cans to the tables and filling machines.

Different types of preparation tables have been devised for handling different products and no one is best under all conditions. For small factories working upon a variety of products, it is doubtful whether anything has been brought out that is better than a plain table with the top slightly inclined backward. Two shelves at the rear may serve to carry the conveyor for delivering the stock and removing the prepared material from the table or they may serve for holding the cans. The stock is delivered preferably in oval pans of not greater than 12 qt. capacity. Each worker has two or three pans, one for the incoming stock, one for the first-grade prepared stock, and one for the standard grade. The waste is returned in the pan in which the stock was received or it may be dropped through a hole in the table to a pan on a shelf below. Pans of the size indicated do not carry scalded tomatoes or soft fruits to a depth to cause them to mat together, the large surface allows heat to escape readily, and the volume permits the peeling within a few minutes. The oval shape conserves space on the table and is most convenient for the workers. The special feature is that the pan can be sprayed after each usage and thus more nearly fulfills the conditions for cleanliness than in any other system.

By the installation of faucets and a trough at the back of the table the same equipment may be made to serve divers purposes. The top is made to pitch backward slightly to protect the workers so that any water or juice may be collected in the trough. This table is superior to any provided with wooden boxes.

A more elaborate table, designed for permanent and large factories, is constructed with bins of porcelain, enamel-coated, stainless steel, or monel metal, provided with water supply, overflow, waste line, also a conveyor system to bring on the raw materials and gates to divert it into the bins. A series of shelves takes care of the can-conveying system and the filled cans while waiting inspection. This style of table has been standardized even to the number of units best suited for a line. The tables are heavy and permanently set in place. They are frequently provided with adjustable seats for the workers. In the pan system previously referred to, the product is usually packed into cans on a special filling table or by machine, while with this one the products are most often packed directly into the cans.

Any belt-carrying system should be short and as simple as possible, and provision should be made for continuous spraying of the belt at some point. Belts are inherently difficult to keep clean and elaborate systems are unnecessary in any well-planned layout.

Can-delivery systems are so nearly perfect that cans are delivered wherever wanted at filling tables or machines. A provision which needs to be incorporated is that each can be inverted and washed before it reaches its final destination.

Filling the cans may be either a hand or machine operation, depending upon the product. Nearly all fruits are hand-packed, the principal exceptions being solid-packed apples and pie peaches. Tomatoes may be hand- or machine-packed. Peas, corn, baked beans, kidney beans, hominy, milk, and soups are filled exclusively by machine operation. Asparagus is hand-packed as is also the asparagus style of string beans. Other string beans, spinach, kraut, fish, and meat may be either hand- or machine-packed. A number of very interesting machines have been developed to do the work to a very high degree of perfection, measuring or weighing the solids and then adding the correct amount of sirup, brine, sauce, or salt as separate operations to obtain an exact fill. The full automatic machines have been developed to a very high speed. Among the simplest of the hand-feed type is the Lowe table in which the cans pass under a feeding ledge, the product is delivered into the center of the table, and about four persons fill the cans at approximately five times the speed that can be maintained on the ordinary table.

The equipment which follows, *i.e.*, the exhaust box, closing, cooking, and cooling devices are of various designs depending upon the product to be handled and the amount the canner is willing to invest.

The simplest exhauster and also cooker is the galvanized-iron pan set directly over the fire. It is not obsolete, though not at all common in factory equipment. Those now made are chiefly for home or community canners. The next development was the box tank with water heated directly by steam or a steam coil. The work is done in batches, is slow, irregular, and costly; it is justified only for small operations such as home or community canning or where there is a small amount of material available. The usual exhaust is a continuous process with the cans carried through the heating chamber on a conveyor, the line of travel being made as long as possible to give time for heating the contents. There are commonly two types in use: the chain or cable, conveyor style, and that with rotary disks. The heating may be by water or steam. The water type is capable of being operated at any degree up to boiling but preferably below 200°F. and timed up to 8 or 10 minutes. They are more elastic in operation than the steambox and also more positive in action. No data are available to show the comparative costs of steam and water

exhausting, though theoretically the latter should be the more economical. The steambox is a little simpler in construction and costs less in the initial outlay.

The open-top can is so universally used that few factories except in the milk- and meat-packing lines use any of the solder type. Simple double-seaming equipment is available at such low cost that solder-top cans have nearly disappeared even for home use. The shift from one type to the other has taken place since 1900. The principle is that of rolling the edges of the cover and body together under such strong pressure that they form a tightly compressed hook within which the sealing compound makes a hermetic closure. The simplest hand devices will close from 4 to 5 cans per minute while the multiple spindle power machine will close 150 or more cans in the same time. They are also made so that the can may be sealed while in a vacuum chamber, or an inert gas may be introduced to take the place of air. Mechanical exhausting and sealing is rapidly displacing heat exhausting in certain lines as in salmon and other fish packing, for pineapple, and for the handling of some other fruits.

The cookers vary from the simple forms, which are also used as exhaust boxes, for batches or continuous feed without pressure, to retorts for batches with pressure, and to continuous cookers with or without agitation and with or without pressure. This part of the equipment has been improved until almost any sterilizing condition can be met with certainty of control in time, temperature, equalized container pressure, and without agitation or given as much as desired. In the latest type the can becomes the unit with all treated alike and this is carried to preheating before the sterilizing cook and to the cooling subsequent to that operation. Steam, water consumption, space occupied, capacity, accessory apparatus, and labor in operation, all become factors in making a choice for a particular purpose.

CANNING OPERATIONS

The various factory operations which are necessary in the handling of the majority of canned-food products may be divided among the following headings:

Grading.	Exhausting.
Washing.	Cooking.
Peeling.	Cooling.
Can washing.	Coding.
Blanching.	Warehousing.
Filling.	Can cleaning.
The addition of brine or sirup.	

There may be various changes in sequence of the above operations, and in many instances combinations of a number of operations in one

procedure. With each product certain variations may be introduced because of particular characteristics which require special treatment and others where the entire procedure is extremely simple. The discussion is designed to enable a general consideration of such processes rather than to be specific for any given product, although examples are cited in a few instances.

Grading.—Grading is one of the most elastic terms occurring in the canner's vocabulary, meaning much or little depending upon who uses it and the circumstances. To the public the term conveys the impression of differences in quality or degree of excellence that is distinguishable to the purchaser or consumer, whereas in the case of fruits it may refer only

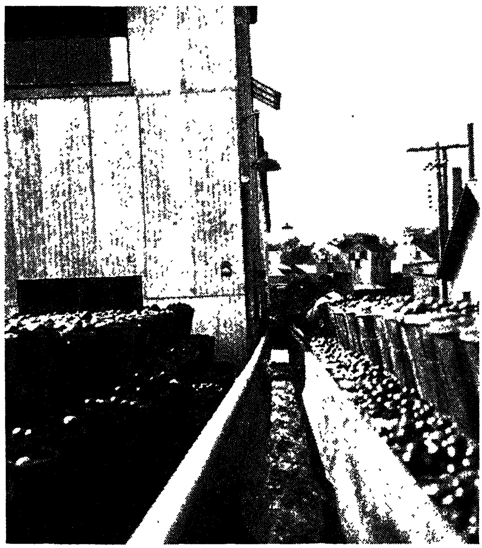

FIG. 54.—Sluice for conveying tomatoes. (*Courtesy of Food Industries.*)

to the strength of sirup used. Trade definitions for grades have been formulated for the guidance of packers and buyers but are little known to the consumer who is the one most concerned.

Strictly uniform grades are obviously impossible for the reason that nature does not produce the same result in plants when grown from the same kind of seed planted in the different sections of the United States. This variation in quality in the best plants grown in the different sections is often greater than in the select and field run as grown in the more favored localities. Good illustrations are to be found in such vegetables as beans, peas, and asparagus, and such fruits as the peach. It would be difficult to find a more beautiful peach than is grown in Georgia, a more delicious one than is produced in New York, or a larger one than developed in California, each a good quality in itself but differing in kind.

Owing to the abundance of the western fruit and its better appearance after cooking, standards have been set for that fruit which cannot be attained in other sections. It is for these reasons that only the lowest or second grade is required to be designated in labeling, but if other grades are indicated, they must conform to the trade standards.

Real grading begins with the raw product and rapid progress has been made in this respect during the past decade. The government marketing bureaus and the state experiment stations have cooperated in formulating standards for the various raw products, and these have been accepted by canners as a basis for purchases. The difference in price for the grades makes it unprofitable for both buyer and seller to handle the seconds or culls. This excludes a large amount of material which was formerly delivered as orchard or field run and thus reduces the volume of waste and lower grade products. Without good and uniform quality in the raw product, no amount of labor can make up for the deficiencies or turn out something with merit. In the case of other raw food materials, inspection systems have been developed which serve a similar purpose.

Grading within the factory takes on various aspects, one of which is the separation of the product for size. In nearly all cases large size is considered highly desirable and an essential for the first grade, though as a rule size has no appeal except to the eye. In fact, largeness is most often a mark of coarseness in fiber and texture with some corresponding deficiency in edible qualities. A large size is given preference among fruits, while small size is in favor with most vegetables, such as peas, beans, beets, carrots. Mixed sizes are slightly used where fruits or vegetables are packed whole.

Various mechanical devices have been made available for separating the majority of products. These may be in the form of rotary screens, vibrating screens, rollers which are tapered, and thus increase the distance between them, rollers which are offset in decreasing diameter, rollers which spread apart in their line of travel, diverging ropes or tubes, gravity, etc. The choice of device depends upon the product to be graded. In some cases the work is done before and in some cases after other preparatory operations. As a final step, hand selection is necessary to insure separation where a matter of judgment is involved.

Further separation based upon quality is largely hand work as selection for uniformity and best color, which in most instances corresponds to proper maturity as distinguished from that which is overripe, immature, or otherwise defective. It also eliminates that which is spotted, sunburned, marked by fungus or insect attack, or disfigured by defective workmanship. This part of the grading may be a special operation conducted on a belt or at a table, or it may be a part of some other operation, as pitting or in the filling of cans. Grading in some instances may mean

nothing more than the use of sirups of different concentrations and such applies especially to berries.

In the truest sense, grading represents the intangible something, skill or refinement, in the selection and preparation of a product. It is the ingredient which cannot be supplied in any set of formulas or directions, no matter how minutely detailed and is the element which goes to make up the difference between quality and the ordinary product. It is the main factor which enters into the difference in cost between the fancy grade and the standard. With the average run of good raw material almost any packer can put up standards, but many cannot put up more

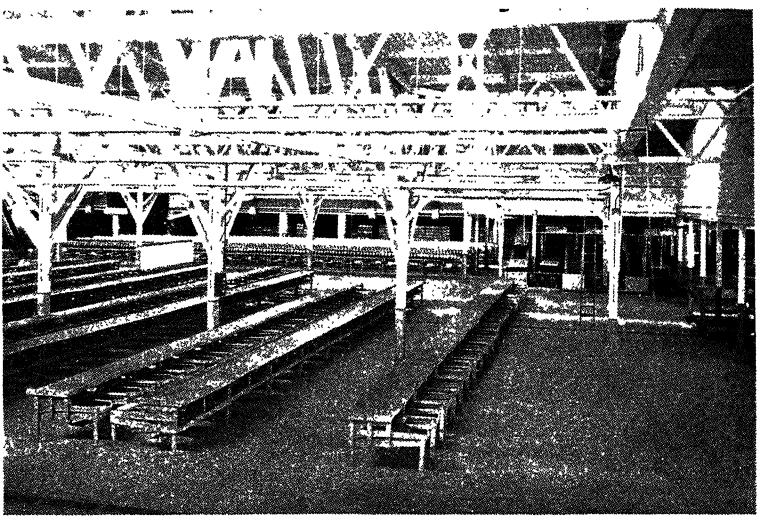

FIG. 55.—Trimming tables in a large cannery. (*Courtesy of Food Industries.*)

than a small percentage of choice or fancy grades. The finest raw material in unskilled hands cannot be made to yield a strictly fancy grade, and the factory that depends upon new help each year can never hope to turn out a product which will be uniform or of real merit.

A fancy product can be secured only from the most nearly perfect stock which is grown in a season. The percentage of such stock will vary from year to year and the fancy of one season may not be the same as that of the year previous. It may be better or not so good, depending upon the caprice of nature, but the average of four or more seasons ought to be nearly the same. It is here that skill becomes the determining factor in pitting, trimming, selecting for size, color, texture, and in filling to give the most attractive and uniform appearance.

The trade recognizes fancy, choice, standard, seconds, and water grades for most fruits, and fancy, standard, and seconds for most vegeta-

bles. Under a recent amendment to the pure-food law, products below standard must be labeled seconds. These grades are again divided on the basis of size, color, variety, etc., so that there may be two or more fancy, three or four choice, and from five to eight standard, and three or four seconds, but these differences are not disclosed to the consumer. Again two or three grades may be combined into one in order to simplify handling.

Washing the Product.—Washing is one of the most essential steps in canning but needs to be modified in accordance with the nature of the material being packed. The sole object is to get rid of dirt and adherent foreign material. If the dirt is dried on the surface of the product, as is common with root crops and frequently with tomatoes, the preliminary soaking is an aid which should not be overlooked. The soaking not only saves water at the sprays, but makes their action more effective. By a soaking tank is meant more than a mere box or tank in which to dump the product, but a compartment large enough to receive the stock and hold it for the time necessary to loosen the extraneous material. In most instances the time needed is short, not more than 20 seconds, but in others it may need 2 or 3 minutes. A conveyor from the soaker to the washer insures a more constant and even distribution of the product for the action of the sprays.

The spray type of washer is more efficient for nearly every purpose, as none other performs the work so well or so economically. The volume and the force of the water can be controlled to meet every requirement from the most resistant to the most delicate product. The sprays need to be so placed that water will come in contact with every part of the surface or the product turned while under a spray so that all parts are equally exposed to its action. The spray works upon the principle of the nozzle on a hose, namely that a relatively small stream of water under pressure is more effective in cleaning than a larger volume without pressure. The sprays in a washer may need a pressure of 20 to 60 lb. in some cases and only 10 lb. in others. In like manner the size of the openings needs to be varied.

Washers of the rotary type assist the sprays materially because the friction between the product and the drum, or between the separate elements of the product aids in loosening any extraneous matter. This is particularly effective for tomatoes intended for pulp or paste, though a little too vigorous for tomatoes intended for canning, which exemplifies the need of apparatus adapted for each product. In the case of berries floating or on belts, the sprays can be reduced to very fine particles and be effective without causing injury.

The kinds of openings and nozzles used for sprays are legion, from a piece of pipe with numerous holes, $\frac{1}{32}$, $\frac{1}{16}$, or $\frac{1}{8}$ in. in diameter, or slits

made with a hack saw, to the most complicated nozzles. One of the difficulties is that the openings become clogged so that the simpler the better. One style which is more effective than the average is a pet cock with a deflector to break up the stream.

The amount of water discharged through nozzles of small size with varying water pressures is given in the Gould Pump Company Handbook. These are within the range used on washers and the figures may be taken as being approximately correct for the spray type of apparatus and the volume of water needed for operation obtained by multiplying by the number of openings used.

TABLE 98.—WATER DISCHARGE UNDER DIFFERENT CONDITIONS

Pressure, lb.	Head, feet	Velocity of discharge	Gallons of water per minute			
			1/16 in.	1/8 in.	3/16 in.	1/4 in.
10	23.1	38.8	0.37	1.48	3.32	5.91
15	34.3	47.2	0.45	1.81	4.06	7.24
20	46.2	54.5	0.52	2.09	4.69	8.55
25	57.7	61.0	0.58	2.34	5.25	9.34
30	69.3	66.8	0.64	2.56	6.21	10.2
35	80.8	72.2	0.69	2.77	6.64	11.1
40	92.4	77.2	0.74	2.96	7.03	11.8
45	103.9	81.8	0.78	3.13	7.41	12.5
50	115.5	86.2	0.83	3.30	7.71	13.2
55	127.0	90.4	0.87	3.46	7.77	13.8
60	138.6	94.5	0.90	3.62	8.12	14.5

In the case of a limited water supply the spray type of washer may be operated in two sections, the first half or portion may use the filtered return water by means of a separate pump, and the second part use fresh water for rinsing. If the normal water pressure is insufficient, a rotary pump furnishes the simplest means to increase the pressure to that necessary.

Washers are also built on the principle of introducing compressed air to agitate the water and products being treated, and to use propeller wheels or other agitators to secure the same result. These are all improvements over the old methods. Most of them employ the spray for final rinsing. Washers which depend upon raising and lowering a basket or crate of fruit or anything else a few times in a tank do not measure up to what reasonably may be demanded of any washer.

The most important single piece of apparatus used in the making of pulp and catchup to comply with the law is the washer.

Lye Peeling.—The treatment of certain foods with lye in order to effect their preparation is of ancient origin. The olive has been treated

with lye, ashes, and quicklime for centuries, the object being to remove the bitterness in that fruit, and no better method has been devised to take its place. The Indians used wet ashes and the water in which ashes had been soaked to remove the hull from the grains of corn long before the white man came to this country. The immigrants improved upon the method of obtaining the lye and treating the grain, and lye hominy became an important item with the pioneers and continues to be made, though on a small scale.

When it was realized that peaches could be peeled by this method, several persons developed devices for doing the work, such as a tank in which to heat and hold the hot lye, and conveyors for submerging and carrying the fruit through the solution. These were also of the type of the hollow drum with flights on the inside, multiple drums with pockets on the outside, so that the fruit could first be carried through hot water and then through tanks with lye of different strength, and tanks with draper conveyors to submerge and carry the fruit through at a predetermined rate and discharge into tanks of water or under sprays, as in the hulling of hominy. A later device uses the principle of carrying the fruit on an open mesh conveyor and subjecting it to spraying with water. This has the advantage that the lye can be kept at a higher temperature, cleaner, and of more constant strength. The use of sprays for getting rid of the cauterized tissue and adherent lye is the most efficient method thus far developed. Since 1912 this method has practically superseded manual work in commercial packing.

Lye peeling is based upon the fact that a strong solution of caustic alkali will attack cuticular tissue and cause its dissolution. To be successful as a peeling agent, however, the dissolution must be so rapid that the tissue may be removed by washing before the inner tissues are attacked. This makes the method much more applicable to a fruit with a skin like the peach, apricot, or fig, but of no practical value with one like the apple. It is serviceable in peeling young carrots and some varieties of sweet potatoes and white potatoes. It has been tried for tomatoes but requires so much hand trimming that it has not proved profitable. It could be used on catchup stock tomatoes to remove the surface infection of mold. A recent use is to remove the "rag" or white membrane surrounding the segments of grapefruit after the peel has been taken off.

The caustic used for the purpose is sodium hydrate, as that is the least expensive and at the same time the most effective. As the product takes up moisture from the air, it should be obtained of as high percentage of soda as possible and kept well protected.

The strength of the caustic used in the lye bath varies with the fruit and the method of treatment. It is usually between 1 and 3 per cent for peaches where the dipping method is used and somewhat higher for the

spray method. The lye acts most vigorously when hot and therefore is kept close to the boiling point. There is a distinct gain in subjecting the fruit to boiling water for a few seconds to heat the outer layer so that the lye can act without first being chilled by the fruit. The time of exposure to the caustic varies from 20 to 40 seconds. As soon as the fruit is out of the lye, it should be washed thoroughly to prevent continued action by the lye and also to prevent browning. This last change can be averted by short steaming or by immersion in the blanching tank.

Repeated tests have shown that when properly used, lye peeling produces no appreciable effects upon the product. The short exposure limits the attack to the superficial cells and prompt and thorough washing removes any alkali which may be present.

Can Washing.—Persons using canned foods have the right to expect that the interior of cans used for packing foods are as clean as the utensils used for preparing foods in the home. Good machines are available for this purpose in large factories, and hand washing is possible in smaller establishments. No food manufacturer is justified in omitting this important operation.

As the empty cans are conducted along a runway to the filling machines, each one should be completely inverted at some stage in the route. This precaution may avoid numerous instances of injury to the consumer which may result from tacks, small nails, occasional bits of metal, stone, or glass. It also avoids the possibility of insects remaining in cans when they are packed. Legal cases resulting from neglect in this respect have proved costly to food manufacturers, although some accidents are bound to occur in spite of the most constant care.

Blanching.—Blanching or more properly stated, precooking, is commonly practiced in the preparation of most vegetables and with some fruits. The practice originated with Appert and has continued ever since; and while the necessity and advantages of the operation have been questioned, especially for certain products, one can be certain that any operation so generally followed is not without good reason.

The objective sought in blanching is not always the same. It may be to serve only as a hot-water wash, as in the case of young peas where the sticky substance and adherent dirt cannot be removed with cold water; or it may be for the purpose of softening, as in the case of older peas. In the case of asparagus it is to render the spears sufficiently pliable to pack properly and the same reason may be assigned in the case of string beans. In the case of spinach and greens it is to cause the tissues to collapse so that the proper quantity may be filled into a can. In the case of dry beans, etc., it is for the purpose of plumping or causing them to take up water before filling them into the can. Fruits are not generally blanched, but it is a desirable practice to follow, especially with peaches which have

been lye-peeled, as it arrests the tendency to turn brown and gives a more uniform color. It also makes them more flexible so that they pack better in the can. Careful blanching lessens the tendency to split the skin in the case of cherries. Another effect of blanching of some vegetables is to eliminate a certain amount of raw flavor and odor that is objectionable when the packing is done without this preliminary treatment.

It has been recognized that slight losses in food value, particularly from the standpoint of mineral salts, may result from blanching, but this treatment has certain advantages which are difficult to obtain in any other manner.

Doubtless a great deal of blanching is done at a higher temperature than is necessary or advisable. The usual rule is to drop spinach and other succulent vegetables directly into boiling water with the effect that the superficial cells are unduly expanded, burst, and lose their contents. Better results can be obtained at a lower temperature, with less loss, and doubtless this holds for other foods. Blanching in steam instead of water has also been proposed and has been tried repeatedly but not with that degree of success which predicts an immediate abandonment of the old methods.

Depending upon the nature of the product, it may be placed in the cans by means of an automatic filling machine which discharges a certain weight or volume, or it may be done by hand. Many fruits are filled by placing a certain number of pieces in a can, depending on grade, and such materials must be hand-packed. In some instances blanching precedes the can filling, as with spinach. As stated above, the grading operations are often carried on at the time of filling. Generally the empty cans are conveyed by belts to the filling tables, and when the product has been placed in the cans, they are then conveyed to the sirup machines or brines, as the case may be.

Brine.—Brine is as essential to the proper packing of vegetables as is sirup in the packing of fruits. As with the latter, its making should not be treated in a perfunctory manner but should receive the care and attention which it deserves.

The water should be clean and soft. Water containing large amounts of iron or excessive hardness, if used in brine, may ruin the finest peas and beans. The best handiwork which may be bestowed upon a product in its preparation can be nullified by making it hard or imparting an undesirable flavor. If the natural water supply is unsuitable, it should be corrected by appropriate measures, such as filtration, preheating and settling, or the use of softeners. Only the highest grade of table salt should be used.

The brine is usually made in tanks gauged for volume so that the correct amount of salt by weight can be added to each batch. The brine

is brought to a boil, mixed, and strained into a holding tank. The percentage of salt most often used varies between 1 and 3 per cent, with 2 per cent as an average for the majority of vegetables. Where only a small amount of brine is used in a can, a 3-per cent brine may be necessary to give the proper flavor. Caution must be exercised not to use too much salt as that error cannot be corrected, while if the amount is slightly below the average liking, adjustment may be made at the time the food is prepared for the table. The amount used should be sufficient to take away the flat vegetable flavor.

Brines are almost always made by adding a weighed amount of salt to a given volume of water. One pound of salt added to 12 gal. of water gives very nearly 1 per cent, so nearly that it is safe to use this ratio in making up any percentage. The salinometer is seldom used. This instrument instead of reading in percentage of salt, is graduated in parts per hundred of saturation, which is practically four times that by weight. Four degrees on the salinometer corresponds to 1 per cent of salt. Enamel- or glass-lined tanks are best for making and holding brines.

In two products, peas and corn, it is customary to add sugar to the brine.

Sirup.—Sirup is an essential component of all high-grade commercially packed fruits. Even the finest quality fruit must have added sweetness to satisfy the desires of the consumer, even though it may be only slightly acid in character. Distinctly sour fruits without sirup have practically no demand, except for a limited use by diabetic patients who must limit the quantity of sugar in their diet.

The ability to produce sweetness is not the only function of sirups in canned foods. The use of sirup helps to conserve natural fruit flavors and tends to mask metallic flavors which may result through the interaction of fruit acids with the iron of the can. It also is an aid in fixing fruit colors and it lessens the formation of lake and bleaching due to the tin. The more concentrated sirups have a strengthening effect on fruit tissues, owing to osmotic changes, which tend to prevent the disintegration of the edges and cut surfaces of fruits such as apricots and pears, which otherwise may present frayed and seemingly torn surfaces. Similarly, heavy sirups prevent the disintegration of soft and fragile berries. Sirups of the heavier grades also display a mechanical advantage when used because they lessen the mechanical injury otherwise likely due to the various pieces in a can bumping or bombarding each other when the can is handled roughly in transportation. The heavy sirup acts as a cushion or shock absorber.

Present practice is to use sirups made to certain densities or percentages of sugar for the various grades of the different products. Thus, if a choice grade of apricots or peaches is given a 40° sirup, that is followed

irrespective of the natural sugars or the acidity, and similar treatment holds good for other grades and other fruits. Such a scheme insures standardization of factory operation, but it eliminates individuality or skill in producing the best possible result. It would seem as though there were possibilities along this line not yet realized. The present practice, however, is much better than the old without any definite standards.

The sirup needs to be made from the best grades of granulated sugar. There is no difference between cane and beet sugars, though tradition often gives preference to the former. Soft sugar, even though of the

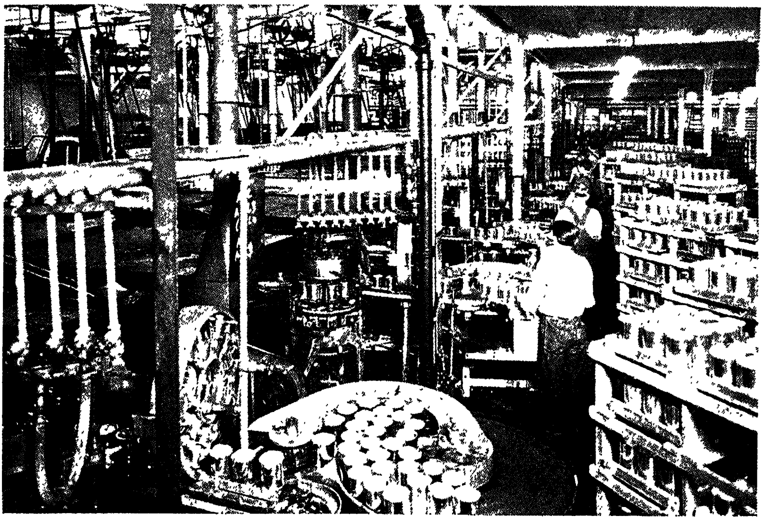

FIG. 56.—Siruping and exhausting. (*Courtesy of Food Industries.*)

lighter color, is not suitable for the highest grades of canned foods and usually the difference in cost does not warrant its use even for standards or lower. Saturated sugar sirups have been introduced as a means of avoiding the cost of granulating, and such sirups may be delivered to the canner in tanks on cars or trucks.

Corn sugar has recently been declared by authorities of the U. S. Department of Agriculture as on a parity with sucrose (cane or beet sugar) without the necessity of declaring its presence. The relative suitability of corn sugar in comparison to the other types of sugar for sirups used in the canning industry is not yet a settled question.

The water used for making sirup must be pure and should contain as little mineral matter as possible. Unless it is capable of making a sirup which is bright and clear, with no floc after cooking, the water must be subjected to some previous treatment. Sometimes a heat treatment and sedimentation previous to using for sirup will suffice, otherwise more extended processes are necessary.

The method of making and handling the sirup will depend upon the quantity of sirup used. The simplest method is to use jacketed kettles or tanks with coils and to graduate the fill to definite weights or volume on measuring sticks so that when the kettle or tank is filled to these points, a certain number of pounds of sugar added will give a sirup of the desired degree. When making the sirup, the sugar and water need to be well stirred while heating, otherwise there will not be an even diffusion. It is better that there is a short boiling period and the sirup filtered through heavy flannel or canton flannel as it goes to the storage tanks. A few manufacturers place the sugar upon racks or platforms and permit water to trickle through it, dissolving it, and then passing it directly to the storage tanks. The amount of water is regulated so that the solution will be of a high density. Filter cloths are placed on the racks so that the effluent sirup is clarified.

It is essential that sugar tanks are of such construction that they may be readily cleaned and sterilized to lower the instance of thermophilic bacteria. (See chapter on Sugar.)

Whether the sirup be made by boiling or percolation, it is checked for density by means of the Balling or Brix spindles. The reading upon the spindle gives the percentage of sugar in the solution, while that upon the specific gravity or the Baumé spindles requires that the readings be compared with a table in order to get their significance. The Brix spindle is used in chemical analysis and is so nearly the same as the Balling that for factory purposes they may be used interchangeably. The sample should be cooled to as nearly 60°F. as possible, otherwise corrections for temperature become necessary, and chances for error are introduced.

TABLE 99.—AMOUNT OF SUGAR PER GALLON IN SIRUPS

Density, ° Balling	Quantity of sugar		
	Ounces	Pounds and ounces	
5	7.0	0	7.0
10	14.8	0	14.8
15	23.5	1	7.5
20	33.3	2	1.3
25	44.5	2	12.5
30	57.1	3	9.1
35	71.7	4	7.7
40	88.8	5	8.8
45	109.1	6	13.1
50	133.4	8	5.4
55	163.0	10	3.0
60	200.0	12	8.0

Whether the sirup be made directly to the degree wanted or made as heavy as 50 to 60° depends upon the factory requirements and the equipment. In the smaller factories heavy sirups are made and used as stock for diluting as the needs arise. The sirups most used are 55, 40, 30, 25, 20, and 10°. A 40° sirup can be diluted to the lower degrees with little chance for error by using tanks which have been properly calibrated for the different proportions of heavy sirup and water.

To make a sirup varying by 5°, using 1 gal. of water as a basis, requires the addition of sugar as shown in Table 99.

The standardized sirups are held in tanks the capacity of which varies from 200 to 1,000 gal., depending upon the volume of the packing. A pipe line leads to each siruping machine so that the distributing system usually requires from four to seven lines. They are usually of galvanized iron. Long lines and many fittings favor rusting and the accumulation of undesirable materials. It is desirable that the sirup room be centrally located so that the pipes may be short. One weakness of the system is that the sirups are warm, and standing favors the development of heat-resistant organisms, which fortunately is not a serious matter in the canning of most fruits though a potential source of trouble for vegetables. The longer the line and the more fittings and valves, the more difficult it is to clean and sterilize.

The sirup is usually filled into the cans by machines. If the same machine is used with sirups of different concentration at different times, the reservoir from which the sirup is drawn should have a small capacity. Such changes, which are frequent in small factories, would otherwise result in filling a considerable number of cans with sirup of the wrong concentration.

A more recent type of sirup filler enables the use of only one densities of sirup regardless of how many different degrees of sirup are used in various packs. The machine delivers the proper amount of heavy sirup and a simple valve adjustment regulates the charge, so that when diluted with water, the can will have the resulting density of sirup desired.

The addition of sirup may be accomplished manually, as is more likely in small factories, but machines are commonly used for this purpose. The automatic fillers are more economical both from the standpoint of labor costs and the elimination of waste due to spilling.

The amount of sugar required per case of fruits is well illustrated by taking California peaches as an example. When well packed, they average about as shown in Table 100.

The test upon the cutout sirup from the cans is not all sugar but sugar and soluble solids from the product. It will be higher immediately after canning than later after equilibrium has been established by osmosis, which will be within about 15 days. The relation of the cutout to the

TABLE 100.—SUGAR POUNDAGE PER CASE, CALIFORNIA PEACHES

No. 2½ Fancy grade, 55° sirup	8.40 pounds
No. 2½ Choice grade, 40° sirup	6.41 pounds
No. 2½ Standard grade, 25° sirup	3.73 pounds
No. 2½ Seconds grade, 10° sirup	1.35 pounds
No. 10 Fancy grade, 55° sirup	10.03 pounds
No. 10 Choice grade, 40° sirup	6.65 pounds
No. 10 Standard grade, 25° sirup	3.81 pounds
No. 1 Tall, Choice grade, 40° sirup	8.41 pounds
No. 1 Tall, Standard grade, 25° sirup	5.00 pounds
The cutout on No. 2½ cans, 55° sirup	27° to 28°
The cutout on No. 2½ cans, 40° sirup	22° to 24°
The cutout on No. 2½ cans, 10° sirup	11° to 12°

sirup used is sufficiently close so that the reading is a good index of what was used, provided the weight of solids is known. The weight of the fruit is important. If a standard fill for a can is 20 oz. and the fill is made 21 or 21.5 oz., the quantity of sirup will be decreased and consequently the degree on the cutout will be low, while if the fill is only 18 or 19 oz., it will be abnormally high. As large fruits, like peaches, pears, plums, etc., have to be filled by the number of pieces and not by exact weight, an average of three cans should be considered as a sample rather than one. The amount of sugar per case for the different fruits will vary, but the ratio of fruit to sugar will be fairly constant.

Exhausting.—Exhausting consists in the removal of a part of the gases from the product or container prior to sealing and is most often accomplished by heating or the application of a mechanical vacuum of greater or less degree. The practice started almost with the beginning of the art as a result of the work of Gay-Lussac who believed that decomposition consisted in a series of oxidation processes, and that by eliminating the air as much as possible the tendency to decomposition was reduced accordingly. The result was that almost as soon as the tin can came into use, the practice of heating and then venting was started. A small hole was left in the cover and this was not closed until after the can had been heated, or the hole might be closed and the can heated and punctured to let out the expanded gas and then closed as promptly as possible. A second object of the hole in the cover was to make the work of soldering easier. The necessity for getting rid of any gas within the can became so thoroughly established that venting was a common practice especially in meat and fish packing until 1900. Mechanical vacuumizing was not so generally used as heat and had its greatest usage in the canning of meats. This was most often accomplished by introducing the can into a vacuum chamber, puncturing the can, and then sealing before releasing from the chamber. In 1914, Malmquist developed a machine for sealing the open-top can within a vacuum chamber just large enough to hold one

can at a time. This became a line operation and was adopted largely by the fish packers of the Pacific states. Many improvements have been made in the machine and the principle is now being adopted in many lines of packing.

While it is now known that the original objective was based upon a mistaken idea, there are other benefits from the use of vacuum which makes it indispensable. One is that with a good vacuum the ends of the can are drawn in, which is everywhere accepted as evidence of soundness, while bulged ends are associated with the opposite condition. Neither of these deductions may be strictly correct, but it is the best guide the consumer can follow and works no great hardship upon the careful packer. It reduces the tendency of overfilled cans to distend upon being carried to a hot climate or high altitude, and also reduces chemical action between the food product and the container, thus largely eliminating hydrogen swells.

Heat exhaustion needs to be varied with the product. It may be as low as 130°F. for some products which have little or no action upon the container and with others should be at least 165°F. At this latter temperature, no cans are ever overfilled. For large cans such as No. 10 an exhaust above 140°F. causes such a strong collapse as to present an appearance of having been roughly handled. One of the advantages of heat exhaustion is that the cans enter the cooker at a uniform temperature and thus contribute to greater uniformity in cooking.

The choice of apparatus to be used depends upon the product to be packed and the space available. The first choice is a hot-water exhaust box for the reason that the heat can be regulated at a lower temperature and more closely than by steam and the heating is somewhat more rapid and uniform. Slow heating and holding for a sufficient time to drive the gases out of the tissues is ideal, but in the endeavor to get volume through the machine the general practice is to heat in steam at as near the boiling point as possible and to cut the time. The slow exhaust is best for delicate products like many of the fruits and for all products which attack the can with more than ordinary vigor.

Mechanical vacuumizing has found its greatest usefulness in the preparation of fish. This product needs to be well exhausted, and to do so requires steam or hot-water boxes of unusual size which in turn occupy much floor space and necessitate large steam capacity. The vacuum-sealing machine solves both these difficulties. Within recent years the use of vacuum closing has made rapid headway with the packing of fruits and vegetables.

Cooking.—The term cooking will be used instead of "processing" as it is more nearly correct and is expressive of the heat treatment irrespective of the degree of temperature used.

Cooking involves two considerations, first, that the food be subjected to a temperature of sufficient degree and of time to either destroy or inhibit all life activities; and second, to avoid injuring the quality of the product. To accomplish both of these ends at the same time is not always easy and in case of doubt it must be resolved on the side of safe keeping. The first factor is referred to as sterilization, though strictly speaking not all cans are sterile, but suffer neither change nor spoilage. If this factor were the only one to be considered, the solution would be simple as all food could be given a sufficiently high cook to insure their keeping.

The following are some of the points which need to be considered in arriving at the proper cook.

1. *The product itself* must be considered with reference to the effect of varying degrees of temperature for there is a wide range in the resistance to breaking down under the effect of heat and also in the resistance of the accompanying organisms. Fruits are ordinarily cooked at the boiling point of water and for the most part are easily sterilized within a short time. When the temperature is carried above that point, the flavor is affected very quickly, though naturally with some fruits the changes are more marked than with others. Recent work shows that fruit juices sterilized at from 165 to 185°F. but for longer periods, are so much superior to those treated at boiling that it is strongly suggestive that experiments in canning should be directed along the same line. The outstanding exception to the rule of using boiling temperature with fruits is the olive which is required to be cooked at 240°F. for 40 minutes. Hawaiian pineapple also is being given a temperature of 220 to 224°F., in a pressure cooker, but in this instance it is for the purpose of obtaining a deeper color.

Most vegetables stand a temperature of 240°F. for 20 minutes or more without serious injury to the appearance or flavor, but as they approach 250°F., or exceed that point, destructive changes take place, the product softens, the color darkens, the flavor passes from "cooked" to "strongly cooked," or "scorched," and sometimes the odor is noticeably changed. The skilful packer therefore endeavors to get the cooking operation high enough to destroy the resistant organisms found on this class of foods and at the same time keep below the point at which objectionable changes occur. Milk will not stand a decidedly heavy cook without being injured. Some fish will stand practically the same cook as meats while others cannot be raised to 240°F. without injury.

2. *The character of the organisms associated* with the product have an influence. While the great mass of these organisms are the ordinary soil forms, there is plenty of evidence to indicate that their behavior is not the same under all conditions. A safe cook for a given product in one locality may not be safe for the same kind of product in another. The

young pea in the pod is not sterile, nor the grain of corn before the husk is damaged or removed, but the peas and grains of corn become infected principally in handling, so that the temperature for sterilizing may have to be varied in different sections. Green beans carry the infection on the surface of the pods and they likewise need different treatment according to the localities in which they are grown. Dry beans from the West coast and Central states require different times or temperature for sterilization. The cooking operations generally used are those which have demonstrated a suitable margin of safety based upon extensive cumulative experience, rather than as a result of specific information derived from studying the specific types of microorganisms which might be present. There is need for further research concerning optimum and safe cooking operations in different sections, which might make it possible to use less rigorous methods with safety in some areas.

Heat-resistant laboratory strains of *Cl. botulinum* have been used to determine the heat treatment necessary for canning various foods because on rare occasions botulism has been reported as caused by the use of canned foods. The use of such strains has been on the assumption that foods should be treated sufficiently to kill organisms of equal heat resistance. All bacteria of this species are not equally heat-resistant, however, and some strains are less resistant than other bacterial organisms with which they may be associated in nature. Such studies as have been made with the heat-resistant strains dictate the time and temperature to be used in cooking foods at present, however.

From the standpoint of the canner, one of the advantages resulting from such studies of heat resistance has been the necessity of keeping accurate cooking records in order to meet specific time and temperature requirements, a practice which in earlier days was often carried out with less care than was desirable.

3. *The natural acidity of the product* has a marked influence upon sterilization. As a general proposition, the more acid a fruit, the more readily it may be sterilized. In most instances fruits are strongly acid in comparison with vegetables. The cranberry is one of the most acid berries and will keep for weeks or months submerged in water without heating or sealing. Long before the art of canning was developed, wild gooseberries, damsons, and haws were bottled and sealed either hot or cold and at least a portion would keep. In France and Germany the practice is to heat the more acid fruits to only 185°F. while those which are less acid are given from 195°F. to a boiling temperature. The success of much of the home canning of fruits depends upon the fact that they are made safe at these low temperatures, for in following many of the recipes the contents at the center of the jars do not reach the degree which is assumed, *i.e.*, 210°F. or above. There are numerous apparent exceptions to the general

deduction with respect to acidity, owing possibly to having only part of the facts. One finds acid apricots which are more difficult to sterilize than a less acid variety. The currant, which is a highly acid fruit, is more difficult to sterilize than some berries which are less acidic in character. The elderberry is rather hard to sterilize and the blueberry one of the easiest. Pasteur was the first to call attention to the fact that acid substances are more easily sterilized than those which are neutral or tending to alkalinity. Duckwall called attention of canners to the effect of acidity as affecting sterilization of fruits and vegetables in 1911 and Cruess advocated the addition of an edible acid such as citric acid to vegetables to make sterilization easier, in 1918.

The hydrogen ion concentration or pH of various products is helpful in determining the degree of heat treatment necessary to ensure safety in commercial operations. The determination of pH values enables one to learn the true acidity of a product, which is a more accurate index of acidity than titratable acidity. In general the lower the pH value a product has below pH 7.0, which indicates neutrality, the more readily it may be sterilized.[1]

4. *The volume of infection* plays an important role in sterilization. A recognition of this fact was made by deduction long before it became established by direct experiments. In the packing of corn and peas, when loads are held on the wagon or dumped in piles to be held over night, it is the usual practice either to raise the temperature or to give a longer time in the cook. The time may also be extended a few minutes toward the end of the day if an opportunity has not been given for a general cleanup, and is also extended as the season advances. The same procedure is followed in the packing of white beans, kidney beans, and hominy, when the material is held in the soaking tanks for an unusual time or if the water should be warm, as may occur in summer. Experiments with these products, and also tomatoes, duplicating the conditions which give rise to incipient spoilage, confirm the need for heavier cooking when the organisms have greatly increased in numbers.

It has been known for a long time that the number of organisms or volume of culture used in sterility tests influences the results. In 1913 Esty applied the same technique in work upon corn and peas and thus confirmed by laboratory methods the correctness of the deduction from canning operations.

5. *The initial temperature* of a product upon entering the cooker is important. The temperature to which the containers are subjected in the exhaust determines the vacuum when heat-exhausted, and the temperature at which the product goes into the cooker, assuming that the

[1] See Bigelow, W. D. and P. H. Cathcart, *Bull. L* 17, National Canners' Research Laboratory, 1921.

steps follow in reasonably close sequence. Forecooking, such as in the preparation of cream style of corn, has a like effect. Efficient or inefficient handling at this point may make a difference of from 50 to 75°F. in the cans, enough to materially affect short cooks or those in which the materials have poor conductivity, especially where the cans stand still in batches. Number 2½ cans of water with temperatures of 70, 100, 140, and 180°F., respectively, set at the same time into a bath at 212°F., show nearly the same temperature in 4 minutes (about 205 to 208°F.). These temperatures do not approach so rapidly if the experiment is made with string beans or peas, and only very slowly if sweet potatoes are used. Other products show all gradations between these extremes so that the initial temperature is important. With the agitating cooker it is of less concern than where the cans are quiet, but the best practice is to keep it high and as uniform as possible.[1]

6. *The rate of heat penetration* within the product is of importance. Heat penetration is always more rapid by heat convection currents, as in a freely moving liquid, than by conduction as in an amorphous material like sweet potatoes. One of the clearest illustrations of the effect of this factor is seen in the packing of whole-grain corn and cream corn. In the former, the whole grain is in a brine and in the latter, the cut grains are in a starchy pulp. The raw material is the same, the organisms are the same in kind and probably not very different in numbers in the preparatory stage, but in the former case the heat penetration is so rapid that sterilization is accomplished at 245°F. in 35 minutes while in the latter it needs 248°F. for 75 minutes. Another equally striking example is that of stuffed cans of spinach. Under regulations requiring can stuffing, the heat did not penetrate uniformly throughout the mass and the consequences are known to have been disastrous. A condition analogous to that of spinach has occurred many times in soft fruits. The pieces of fruit soften under the heat, mat together, and the sirup circulates around the mass instead of passing through it.

The rate of heat penetration in all products having any free liquid is greatly augmented by agitation. Heat is carried not only more quickly, but more uniformly to every part of the food product. It was at first believed that this principle would have little effect upon products like peas, but such is not the case. It has introduced a new factor in sterilization, that of quick heating and cooling, which so far has not been evaluated. A product is sterilized in less total time when the changes in temperature are effected quickly than when they take place slowly.

The position of the can in the bath or retort has an effect upon the rate of heat penetration. This was suspected a number of years ago as

[1] Magoon and Culpepper have contributed much information upon this point in *U. S. Dept. Agr. Bull.* 956.

disclosed in one or two patents, but no proof or data are presented in support of the statements. In 1926 and 1927 the writer found from experiments with gallon cans placed horizontally and cooked with other cans in an upright position, that those in the longitudinal position were rendered sterile while some of those standing were not sterile, when the cook given was near the borderline. This resulted in experiments which demonstrated that the convection currents in a can or jar in the standing position follow up the outside, become more rapid as they rise above the middle, are deflected inward near the top and turn downward but sweep outward before they reach the center of the jar. A cold cone results below the center with the apex at the top and the base about ¾ in. from the bottom of the jar.

In the canning experiment cited above, glass jugs of quart and gallon capacities were used. They were coated on the inside with heavy agar which was drawn to points at different distances from the side of the jug and also had dye squeezed into the points at different heights. Water was added and heated which disclosed the movement of the convection currents as described. This work has since been corroborated by the use of thermocouples to measure the temperature.

When the jugs were placed horizontally and the work repeated, a very different picture was presented. The convection currents rose almost directly from the bottom with less following of the contour of the container. The time required in heating all parts was reduced from 15 to 30 per cent in all fluid media but not with equally good results when there was a combination of liquids and solids. This aids in explaining some of the results obtained in the agitating cooker. It also verifies the correctness of the system now generally used.

The effect of the position of the can in a batch sterilization is most noticeable in the case of milk. The outer layer of cans in the cages act as baffles to protect the inner cans so there is some lack of uniformity in the product even in the same batch. The cause of this was not understood until the can became the unit in the continuous agitating system. The differences in treating a batch can be reduced by having a fairly large bleeder valve so that the steam is kept circulating in the retort instead of being blocked or pocketed.

7. *The Effect of Prompt Cooling.*—It is well known among laboratory workers that if a narrow margin is used in the sterilization of media, the test tubes or flasks must be taken out of the steamer or bath immediately after the heating and allowed to cool. Media allowed to remain in the heater and cool slowly with the apparatus are prone to have a percentage of spoilage. The same phenomena occur in canning vegetables. Corn given a cook at 250°F. for 60 minutes and cooled promptly may show no spoilage while a crate taken from the same retort, not cooled, may show

swells due to some heat-resistant forms. If a large quantity of such a pack is stacked while warm, flat sours may result, owing to thermophilic forms of organisms. The same conditions are found with other vegetables though to a lesser extent. The safe procedure with all vegetables is to give the full cooking time in the retort and then cool, not depending upon their latent heat to complete the sterilization. Less trouble is experienced in this respect with fruits though instances have occurred following similar lines.

That these various steps have an effect upon the food product must be considered. The rate of heating vegetables in exhausting does not

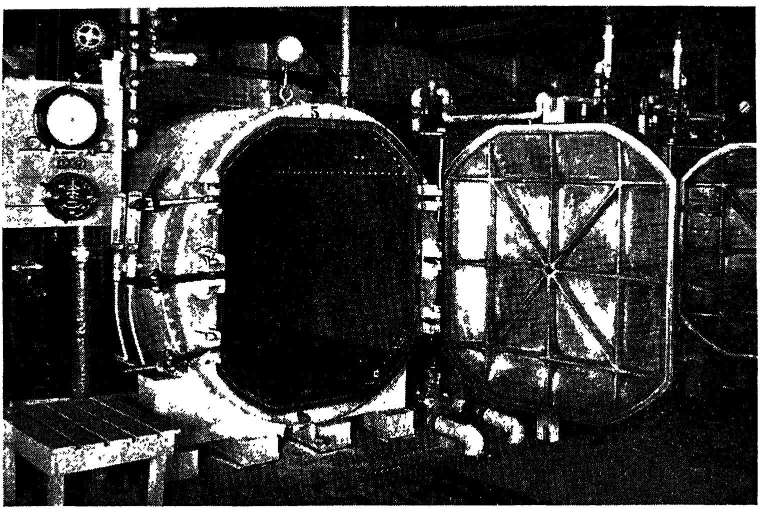

Fig. 57.—Steam-pressure cooker. (*Courtesy of Food Industries.*)

seem to produce any marked effect, but it is of moment in the packing of high-grade fruits. The tissues of soft fruits are delicate and separate under the action of heat if too quickly or vigorously applied. The effect of a violent exhaust is to soften and mush ripe peaches, apricots, plums, and pears, and to cause berries to mat together in the can. A moderate heat, 160 to 170°F., with a good sirup, promotes osmosis, toughens the cells slightly, and holds the appearance. The tissues are exhausted without complete collapsing, the difference being that it takes a longer time, but this is compensated for in part by a lesser consumption of steam. If a mechanical exhaust is used, there should be a gradual heating in the cooker in order to avoid rupturing the tissues in the initial stages.

The almost universal custom in this country is to use boiling temperature as best suited for cooking fruits. This is safe and in the light of experience may well be adhered to, rather than to adopt the methods of the French or Germans, until the safe lower limits are determined.

Another advantage of the lower temperature, in addition to the appearance, is that there is apparently a slowly continuing development in flavor. The latter requires substantiation by experimental procedure before acceptance.

The cooking should be carried to the point where the fruit is in its best condition for consumption, which is generally a little less time than is required for sterilization. The agitating cooker secures a more uniform cook than is possible in a quiet state. The amount of agitation required is slight, barely enough to cause separation of the pieces. The softer, riper, and more delicate the fruit, the more damage from rapid agitation and conversely, the more good from very gentle agitation. Few who have had experience question the advantage of agitation on fairly firm fruits, but there is a difference of opinion with respect to its use on the delicate types. Fruit soup may result from using an agitating cooker, and fruit mush may result from cooking quiet cans too long. In one case it is partly a mechanical breaking and in the other disintegration due to heat.

Experiments in packing tomatoes showed that less than 7 r.p.m. of a No. 2½ can was not sufficient agitation. The contents turned as a whole so that the behavior was nearly the same as a can not agitated but resting on its side. Cans rotated more than 18 times per minute caused breaking of the fruit. The best results were obtained when the speed was about 12 r.p.m. The rate necessary to get the proper effect will vary with the consistency and nature of the product and can be determined only by trial. Some of the objections once raised against the cooker were due in part to an improper operating speed which has since been improved to meet any condition.

In the manipulation of the retort, the temperature cannot be raised so rapidly with hot water as with steam. In the estimation of some packers, water cooking is the superior method. The real factor is the rate of change in temperature within the can, which can be secured by means of steam alone if manipulated to take the same time as with water. This principle has been recognized in the most recent form of agitating pressure cooker, first used for milk but now adapted for other products as well. Instead of admitting the can directly into the retort, it is passed through a preheater which steps up the temperature gradually, and while it is done quickly, it is done with uniformity to the entire contents. The results are so strikingly apparent that the principle has been extended to other products.

Cooling.—The earliest canners allowed their cooked products to remain in the cooker or water bath until the bath itself became cool. This procedure was gradually changed because the necessity for increased capacity required more frequent use of the water bath for cooking purposes, so the cans were removed after the cooking process as soon as they

were cool enough to be handled. A later development was the introduction of valves in the bath so that the hot water could be withdrawn and the cooling period shortened further.

The Baltimore canners were the first to adopt the practice in this country for a definite purpose—to increase the brightness of peas and obtain a clearer liquor. R. P. Scott spread the practice among pea packers all over the country. During the same time the cooling of corn was begun in order to counteract the tendency toward a brownish color. Meyenberg cooled milk for the same reason and also to get a better body, in fact, that product is a failure unless cooled. The real impetus for cooling all kinds of canned foods was given by Prof. S. C. Prescott and W. L. Underwood from their experiments in canning corn and peas in 1898.

Cooling makes possible more nearly accurate time and temperature control over the cooking than when dependence is placed upon allowing the cans to cool spontaneously. It is based upon the assumption that the objects in heating have been fully accomplished and, if not, a few minutes more in the bath or retort will serve that end better than an indefinite time in the open, under uncontrolled conditions.

The work should proceed gradually and carefully as no cooking operation need be timed so closely that reasonable time should not be taken in bringing down the temperature. The practice in cooling varies greatly depending upon the product, in some cases only sufficiently to arrest the cooking, in others to a point so that the cans will be warm enough to insure drying, and in still others to atmospheric temperature. On general principles those products which attack the container most vigorously and those which disintegrate most readily under heat need to be cooled to the lowest degree practical under the local conditions. In no case should they be allowed to go into stacks in the warehouse above atmospheric temperature.

Cooling effectually prevents stack burning, checks any tendency toward excessive softening after cooking, lessens cooked flavor, conserves color, and retards the action of the foods upon the container thereby preventing flippers and springers. It is helpful in preventing flat sours due to thermophilic bacteria. With all these advantages cooling is as much a part of good canning practice as any other factor.

The effect upon the appearance of the product is most important. By arresting the cooking, it tends to keep the product whole as in the case of soft fruits, to retain a brighter color, and in some instances, notably with the tomato, to preserve the natural flavor. With some products like asparagus, beans, corn, spinach, and peas, the cooling needs to be prompt and continued to a fairly low degree, as these foods all become noticeably darker when not cooled. Asparagus and spinach

become soft, while peas lose some of their starch in the liquor. In the case of a few fruits like peaches, apricots, and pineapples in which a deep rich color is preferred, the results are secured by air cooling.

Cooling may be done in many ways, but the most nearly ideal system is that in which each can is treated as the unit as in the continuous cooking and cooling system. The can is discharged from the cooker into the warmest part of the cooler, the can being on its side and rolling. The can gives up its heat in the shortest possible time and emerges from the cooler at its coolest point.

FIG. 58.—Cooling cans by water spray. (*Courtesy of Food Industries.*)

Batch cooling, in either a retort or open vat, is done best by introducing the cold water from the bottom, the reverse from that generally followed. The cold water strikes the can on a filled surface so that there is not the same tendency to cause a vacuum inside as when the cold water strikes upon a part with headspace. That precaution lessens the tendency to buckling and to produce leakers. When the cold water is introduced from below, the hottest water rises so that the cans are protected from the shock from the bottom of the retort to the top. Cooling as generally practiced is by sprays from the top, but the experience of the writer is that the other method is the better.

Instead of cooling in the retort, the crates may be taken out and dropped into cooling tanks and carried through with either overhead or other style of conveyor. The inlet water in the cooling tank should be at the discharge end for the crates and the overflow pipe at about 8 ft. from the receiving end. This creates a dead end for the water and the

cans are dropped into warm water and gradually pass into the cooler water.

In the event of a shortage of water, the cans may be sprayed in the open as the rapid evaporation has a cooling effect. Another scheme for cooling, where water is scarce or not available, is to construct tunnels to receive the trucks of crates and have a fan direct a strong current of air upon them.

Cook Records.—Batch-cooking records first became a part of the routine canning operation with meat packers and such records became a requirement as soon as the packing houses came under the regulations of the meat inspection act. In this matter they were much in advance of other packers. The milk canners also learned the necessity for having accurate records as a guide for their superintendents and it was generally adopted though not made compulsory. The practice gradually spread to fish and vegetable canning, but fruit canners as a rule have paid little attention to it.

Cook-room records are essential to every careful packing concern, and that is particularly true for batch operations controlled by hand. It is unsafe to depend upon retort or batch markers set by hand or electric timers set in the same way. Such devices are merely aids. A record stating the time when a lot went into the cooker, when the temperature reached the desired degree, when the cooking was arrested, and when cooling began, can be checked at that time, the next day, or any other time. Identifying can marks can be added to the record and it becomes a protection in any case of controversy. The only better record is that made by automatic time- and temperature-control devices. In the case of continuous or timed cookers, the daily record should show the set schedule and any changes as they deviate from the schedule.

California is the only state that has fixed regulations for the packing of fish, vegetables, and olives, and requires automatic-recording devices upon the cookers and coding of cans which will completely identify them.

Coding.—Can marking or coding is desirable in any canning operation and a necessity in all, in order properly to identify a package. It may be a very simple matter, or elaborate, depending upon the completeness of the identification and the variety and grades of the products packed by a company. The simplest code is that which identifies the can and its contents with the packing company. Many packing companies, especially those distributing under buyer's labels, do not have an identifying mark, but such should be used under all circumstances. A distinctive cipher stamp on the end or under the label is easily affixed and becomes a means of locating responsibility in case of any controversy. An outstanding mark to identify a product with a firm and so advertised for the enlightenment of the consumer is that used on pineapple.

Code marks are most often printed on the side of the can at the time it is filled. A single letter may indicate the product and the size or style of letter used may identify the year. The grade of the product is indicated by an appropriate letter or numeral before or after the character which identifies the product. The month and day may be indicated by the numerals, although some prefer to give the number of the day in the year and still others use letters. The plant number, if there are more than one, is generally indicated or may be designated by placing the code a certain distance from one end. In extreme cases, the one who packs the can if hand-filled, or the line of machine-packed products, is made a part of the record. Machines have been devised to mark the cans as they are used so that errors in this respect are small.

In California, certain foods are required to be packed under state regulations and the code must bear a mark to indicate the batch, or if processed in a continuous cooker, to show that sterilization occurred within certain hours on the day. This coding requires a second marking after the cooking operation and represents the precision to which the work is carried. In the packing of meat, the government regulations must be followed in the can marking.

An amendment to the Federal food law requires that all low-grade foods, as seconds, be so designated, and a similar requirement applies in California.

It is usual to apply code marks to the side of the can so that they will be covered by the label. Quick drying inks especially prepared for the purpose are used. No ink containing carbolic acid or phenol compounds should be used, as flavor may be imparted to certain foods if the ink is not dry when it enters the exhaust box. Trouble has resulted from this cause. The use of paint is also to be avoided. Die stamping the ends is used only when a few lines are packed and where a few marks may be used without cutting sharply or deeply into the plate.

Another style of coding is to perforate the labels when they are attached. It furnishes a means of identifying the pack by the plant and date, but it is not so complete or reliable as can marking. It is used more particularly upon glass-packed foods.

Correct code marks enable the packer to check back upon improper fill or grades, and in the event of error in cooking to locate the lots affected. In the case of a claim of any kind it is valuable in establishing the facts concerning the lots of goods in question.

Warehousing.—There are a few essentials which need to be considered in connection with every warehouse, and among them none is more important than ample strength in the foundation and supports to carry the load. On several occasions floors have settled or given way with serious inconvenience and loss due to improper calculation of the weight which

had to be carried. Another consideration is that warehouses should be dry in order to protect the cans against rusting, and this in turn necessitates adequate ventilation and its control. It is likewise desirable that the storage rooms be designed to be reasonably cool to keep the foods in good condition and to lessen chemical action between the foods and container. Heat favors the intensity or rapidity of such chemical action, and more damage can follow from two months of bad storage than from a year or more under proper conditions. The temperature in a warehouse not infrequently shows 20° or more higher than necessary, owing to construction, not dividing the floor space, and to stacking cans before they have cooled to proper atmospheric temperature. It is best that the building be frostproof or that it can be heated in cold weather, and it is needless to add that it should be well lighted. It is advantageous that it be located near the cook room and also near the shipping line as it affects the labor costs in moving the product in and out. This is not so important as formerly since conveyor systems are available to handle the product in almost any unit.

Warehouses are often built one story in height in order to save the cost of elevating the goods. The roofs are often of the flat type covered with metal or tar, a form of construction which favors high temperatures in summer and responds quickly to changes of temperature in winter. A distinct gain may be attained by painting the roof white instead of a dark color to avoid absorbing the heat. A second story for the storage of empty cans acts as a good insulator. If the building has only one story, a false ceiling with a dead airspace is advantageous. Partition walls, by breaking up the space, also aid in the control of temperature. Without such precautions the stacks of cans remain warm during hot weather and owing to their compact arrangement, they give up their heat slowly, which naturally favors springers, flippers, pinholing, discoloration, and undue softening of the contents. In case of a sudden drop of temperature in freezing weather, the same flat roof, without an intervening floor or ceiling, chills the air on the inside and condenses any moisture present upon the cans. It is always best to keep compartments tightly closed during sudden changes in temperature, and in the spring it is often best to open the building at night rather than in the day so that the adjustment to outside conditions will follow slowly. In the event foods are frozen, the thawing should take place as slowly as possible. Most fruit is not injured seriously by freezing provided the thawing is not done too quickly.

If a hot-water or steam-heating system is used in the warehouse, an open alley should intervene between the pipes and stacks.

No cans or cases should be stacked on a cement floor, but upon wood strips at least ¾ in. thick. This is for protection against conduction of moisture or change in temperature.

Filling the warehouse proceeds along three general lines, according to the section of the country and the product. In the Eastern sections, if only one product is being packed at the time, as for example tomatoes, the cans are stacked in rows on the side, the rows being made about 6 ft. in height. These rows may be butted against each other making solid blocks or if the packer is of the more careful sort, two rows are butted, then 1 or 2 in. of space left for air, and then another pair of rows. The latter method of stacking is especially advantageous if the cans are not thoroughly cooled. If they are cold and dry, then close packing conserves space. If more than one grade is being packed, separate stacks are necessary. The row scheme is used for permanent stacking by very few. Most canners in the Midwest and Eastern sections are not provided with outside cooling platforms but stack the cans directly from the cooking crates without tapping or testing for leaks. A record of the day's run is kept by the floor area and mark and the number of the tier. Packing on the side is more rapid than on end and also saves a little time in labeling. The exposed ends show the presence of swells or leaks on all outside rows and makes inspection easier. Side packing may also prevent a few leaks. In the case of corn, blackening is not so prominent.

There are packers of corn, peas, string beans, baked beans, etc., who feel so sure of their methods that the cans are packed directly into cases and the cases stacked back to back in rows to the height of the room. This method makes easy and quick handling both in stacking and in taking down for labeling and final shipment. The serious objection is that a burst can be difficult to locate and a box is made so offensive with the odor that it becomes a loss. Packing the cases on the sides, with the bottoms together and a narrow space between the double tiers does much to prevent retention of heat. Another precaution is to have several stacks under way at the same time. The day's record is kept as before by floor area and rows of stacks.

In the warehousing in the West a different system prevails, owing in part to the numerous grades that are handled. All fruits are handled on trays, the unit being the dozen 2½ cans. They are handled from the cooker on trays to the outdoor cooling platform and the next day trucked to the warehouse on the same trays. The system is the same whether the pack is 200 or 5,000 cases per day. The cans are all tested by tapping with a steel, a test which many Eastern factories have never known. They are then stacked permanently where they are to remain until shipped. The cans are set on end, four cans high, and then laths laid across to bind the tiers together. The blocks are made the width of a lath, as long as may be desired and to the height of the ceiling. This requires more time in stacking, also more time in taking down, but economizes considerably in space. Much care is used in keeping the

grades separate and in recording the daily additions. Each of these systems has its advantages and apparently each is best adapted to the place and for the product for which it was developed.

One practice has been growing since the introduction of the continuous cooker and that is to roll the cans long distances to warehouses and even to the point at which they are to be stacked. If rolling is done at all, it should be done very slowly as during the cooling period the strains are all inward and leaks may be developed which would not occur in a quiescent state. Moreover, a long rapid roll of from 200 to 400 ft. while the product is warm may be detrimental to the appearance.

Clean Cans.—It is very important that canned foods present a clean appearance upon the retailer's shelf. Nothing creates a greater aversion to a food than an unclean or damaged appearance and this applies to the container as well as the contents. In the packing of some foods like meats and fish, the outside of the can becomes soiled with grease and oil. It is necessary to remove it by spraying with a lye solution or passing the cans through a bath of hot caustic. This may be done before cooking in the retort, or after, but before cooling takes place. Washing the cans while hot secures the maximum effect with the minimum of lye. The lye solution is then removed by rinsing.

A secondary effect of the vigorous treatment given to get rid of the oil from the product is to remove the oil which was purposely put on to protect the tin immediately after plating. The cans are therefore more subject to rusting and this is particularly true for those cleaned after cooking. Meat cans and salmon cans are, therefore, painted or given a coat of colored lacquer. In the case of sardines and tuna, very little oil adheres to the outside and a much less drastic treatment is given, resulting not only in a bright can but one well protected from rust. Lacquering or painting is unnecessary. Few fruit, vegetable, or milk cans are lacquered in this country because more or less prejudice exists in the trade against such stock. It is objected because of fear that the coating is put on to cover rust or on reconditioned old stock. These same products when shipped abroad are lacquered to prevent rust as that is one of the misfortunes likely to result from a sea voyage. Less trouble is experienced now than formerly as a better understanding exists concerning the conditions which favor moisture precipitation upon the container while in transit. Canned foods are segregated in holds away from freight which contains or is likely to give off moisture with changes in temperature.

Rust prevention has been accomplished more economically with lacquer than by any other agent. The objection is that the medium for cutting the lacquer is usually very volatile, inflammable, and with an objectionable odor, all of which militate against its use in the factory. Some fruits have carried a taste or odor ascribed to absorbing the offen-

sive properties while standing near the lacquering device. It is also alleged that the objectionable material may penetrate the gasket and affect the contents. In one of the latest devices for applying the lacquer, the cans run directly from the cooker to the applicator, the lacquer being dried almost instantly by the hot can and then passing through the cooler. This gives protection during the warehousing as well as later in trade. The ideal substance is one which can be applied either during or immediately after cooking, is without odor or other objectionable qualities, dries quickly without imparting color, does not collect dust, and protects against rust. Cans are made with lacquered ends and depend upon the label to cover any rust upon the sides.

A number of can cleaners are in use. Most of them polish the ends only or merely brush the sides. Cans bearing rust upon the side will develop spotted labels in time and this is most noticeable if the label is white or of a light color. It is best to sort out such cans and use a dark-colored label.

Waste Disposal.—Cannery waste consists of two classes, solids and liquid, the latter carrying soluble matter and also finely divided particles in suspension. The disposition of the former is rapidly taking care of itself in that uses are being found for it chiefly as feed or fertilizer. Products like pea vines, which once were a nuisance, are now left on the farms to be converted into silage. Removal of the vines from near the factory is desirable under any condition as the fermentation which necessarily accompanies the making of silage is objectionable in the vicinity of the factory or residence neighborhood. It is a practical necessity to bring green corn to the factory in the husk so that the amount of waste is bulky. Formerly this was all stacked near the husking shed as were the pea vines next to the viner, but the more up-to-date plants are hauling the husks away to the farms to be fed to stock or converted into silage. Tomato waste can be run through a cyclone to reduce the bulk, then dried, and used as feed. The seeds are rich in oil and are rated as good for both stock and poultry. Waste from dry beans, pumpkin, cabbage, etc., are all suitable for stock feed as it comes from the factory or it may be dried for later use. Fruit pits, as peach, apricot, and cherry are only partially utilized at present. In most cases they are improperly dried and thus reduced in their value. A considerable quantity is shipped to Germany where the oil is extracted, refined, and returned to this country as almond oil. The apricot kernel contains one of the finest salad oils and should be conserved. The majority of pits are used for fuel. Fish wastes are now treated for oil and the residue converted into stock and poultry feeds.

The liquid wastes constitute the part which bring the cannery into contact with health officers and game wardens because of foul odors and pollution of water supplies. The waste waters carrying fermentable and

putrefactive materials are quickly acted upon by bacteria causing slime, stench, and destruction of aquatic life if discharged into a small body of water. A good deal of work has been done through cooperation of canners with health officials in trying to solve the problems, and while some general procedures are applicable to many cases, others have to be handled as special problems owing to local conditions.

The amount of liquid waste at a given factory will depend upon the character of the materials being canned, the abundance of water available for use, and the efficiency with which the water is used.

The first essential in caring for liquid waste is to separate the solid particles as far as possible. A satisfactory method for the purpose suggested by Gust Olne of Reedville, Wisconsin, in 1923 was to use a short section of screen similar to a squirrel-cage pea washer made of fine-mesh wire. The waste from the factory is discharged into the screen and the rotation picks up the bits and carries them to a point where they are dropped into a hopper to be discharged outside.

The effluent, whether partially cleaned in this manner or any other, is conducted to settling tanks built essentially the same as septic tanks. Three are ordinarily considered sufficient for a one- or two-line plant. These tanks permit quick settling and easy cleaning, and suffice where the water can be discharged into a large creek or a river. Septic tanks, though not uniformly successful, if used, need to be of considerable size as the waste is not decomposed so rapidly as in the case of sewage. One of the troubles is that they are slow getting into operation. The so-called brush filters are satisfactory after becoming charged, but as in the case of the septic tank, the short packing season for peas or corn may be half over before the filters begin to function.

Plants located in the country or near small villages can sometimes discharge the waste water upon fields by means of pipes. The surface is divided into squares about 100 ft. on a side and a ridge thrown up about 1 ft. in height. The waste is turned into one plat at a time and allowed to leach into the ground. Liming and cultivating will prevent the place from becoming a nuisance. A plat of 30 to 35 squares will take care of a large amount of waste if the subsoil is not porous.

The means employed in treating or disposing of waste will be dictated largely by the location of the factory and the kind of product, but must be considered fully when selecting a site.

Difficulties Encountered in Canning

Canning is not without its troubles and oftentimes many of them. The cause of most mental unrest and financial embarrassment, from the production side, is lack of training and of understanding of the fundamental principles involved.

Production troubles are generally referred to as those arising from leaks, pinholes, buckled cans, collapsed cans, springers, flippers, puffers, swells, flat sours, stack burns, discoloration, disintegration of contents, foreign odor or flavor, and rarely, food poisoning. Some of these pertain more particularly to the container, some to the product, and some to the method of handling.

No universal container has been perfected for the handling of foods. The tin container is far from that goal but with all its faults it renders a good service when in careful hands. It is light in weight, strong, withstands abuse fairly well, and is economical. Glass is a better container for some products, but not for all. Its greater weight, fragility to shock, lessened output for the same unit of equipment and labor, and extra expense in boxing tends to limit its use to the higher grade products. Its outstanding advantage is that the glass is less susceptible to the action of the product which it contains and that the contents may be inspected by the purchaser.

Leaks.—Can leaks are known as side seam, top and bottom end, cap and tip leaks for solder-sealed cans; side seam, top- and bottom-end seam, and body leaks for the open-top style of can. Leaks are due to the solder not making a proper union or the sealing heads not crimping the ends tightly to the body, or the absence of sealing compound; body leaks are due to imperfect plate or to brittle plate which is fractured in the die press or double seamer. The number of leaks due to defective cans has been greatly reduced with the improvement in testing devices. The majority arise from operating the double seamer at high speed and entrusting it to workmen who do not appreciate the necessity for careful adjustments and who fail to recognize the effects of wear. Displacement of paper gaskets or failure of adhesion of the sealing compound contributes to the quota, but only a relatively small part, if the inspection is what it should be. Large leaks make their presence known by the appearance of liquid or stain and are easily eliminated. Small leaks permit immediate loss of vacuum, but there may be no evidence of loss of contents. Infection with organisms results, and in a short time swells develop. The organisms usually show mixed infection and aerobic types. The small leak is the one which gives most trouble and which may pass into the warehouse unless the cans are tested by tapping. A minute particle of food or a heavy liquid will close the opening and the can remain sterile or unchanged so long as it is quiescent in a warehouse, but become evident upon shipping. The lack of vacuum, presence of rust on the inside, character of the discoloration of the food, and the presence of abnormal quantities of tin and iron in the liquor may be the factors in determining the cause rather than anything learned from inspecting the can. The stripping of the solder seams or the cutting of the crimped

edge may assist in locating defects from poor workmanship. The custom of the milk and meat packers of tapping all cans with a steel before storing or shipping is a precaution which all other packers could follow to good advantage.

A leak-testing device has been developed for use in connection with the continuous-pressure cooker and cooler which tests cans for leaks when they enter the cooker and again when they come out. It is based on the principle that the ends of a sound can spring out quickly on heating and collapse promptly on cooling. Cans which pass through the preheater and the ends do not expand are dropped out for repair, as are also the cans which come through the cooler after processing and the ends fail to collapse. This is far more nearly exact than any human testing and also demonstrates that there are more cans with exceedingly minute leaks than were previously recognized.

Swells are due to the production of gas by microorganisms, either from lack of sterilization or by infection through a leak. When any considerable number of cans swell soon after cooking, without evidence of leakage, and the general run have a good vacuum, it is quite safe to conclude that the trouble is due to lack of sterilization. Apparently sound cans from the same lot, if placed in a warm temperature, generally develop swells in a short time, within from 2 to 14 days, but may be delayed some months if the temperature is cool. The development of swells may be slow in some heavy products like sweet potatoes, squash, pumpkin, heavy-cream corn, and tightly packed spinach, so that the time element must be considered in connection with other factors. Swells may be so mild as barely to distend the ends of the can or so strong as to cause them to burst. The gas is largely carbon dioxide, although other malodorous gases may be mixed with it. The product is most often offensive, sour, and frequently more or less discolored.

The term "puffer" has the same significance as swell and is used more particularly among meat canners than among canners of other products.

Swells are most often due to trying to hold the cook to the minimum in time or temperature, to changes in fill or consistency of the product, or to delay in some preparatory operation without taking due account of the facts in the cook room.

The terms "springer" and "flipper" came into canning terminology with the advent of the open-top can and refer to that form of distention of the ends not due to spoilage caused by microorganisms. In external appearance they cannot be distinguished from a swell and are, therefore, unmerchantable. These cans were first called "springs" in 1907, "springers" in 1908, and the term "flipper" followed in 1909. Cans so designated may show the trouble in such mild degree that only one end may be distended or upon manipulation the distention may pass from one

end to the opposite. In some cases both ends may show some distention during hot weather or at a high altitude and return to normal upon the cans being transferred to a cool place or to a lower level. On the other hand, the internal pressure may be so great as to cause rupture of the can.

Springers may be due to overfilling, to insufficient vacuum, to microscopic leaks, and to the action of the food upon the container. E. W. Duckwall gave the first clear distinction between swells caused by spoilage and springers caused by physical and chemical action in 1910, and the following year H. A. Baker, of the American Can Company made a further contribution upon the subject. Baker also announced at that time that air imprisoned in a can at the time of cooking did not remain as air, but that the oxygen combined with the food substance or the metal. Previous to this, in 1908, Duckwall had pointed out that whereas carbon dioxide was always present in swells, hydrogen gas was present in springers.

Heavy losses were sustained from overfilling when the open-top cans were first introduced. The users packed the cans as tightly as the cover could be applied and it required the experience of a few seasons to determine the cause and the remedy for the springers which resulted. In time it was found necessary to fill by weight or accurate measurement and that has become the universal practice. The trouble did not occur with the use of the hole and cap can for the reason that the seal could not be made when the can was too full.

Springers due to insufficient vacuum occur in foods packed in a cool period without proper exhausting and develop slowly, requiring weeks or months, but may be hastened by storage in a warm place. The products most apt to cause springers are apples, cider, strawberries, sour cherries, and loganberries. When a can is punctured, the gas emitted is hydrogen; it burns on the application of a lighted match and there is no objectionable odor. The product is generally normal in appearance or may be somewhat bleached. The flavor is likely to have an astringency due to the iron. No bacteria are present in a living state. Springers due to the development of gas, especially if they have not reached the hard state, will return in the ordinary cool bath, a test which applies also in the case of over-filling and of insufficient exhausting. The remedy lies in well-filled but thoroughly exhausted cans, the use of inside lacquered cans for certain products, and cool storage. The product in a springer of the kind described is sound but not merchantable.

Pinholing.—Pinholing is caused by the same factors that cause hydrogen springers, by the chemical action of the food upon the container, but in this case instead of being general, the action is localized. The points of attack are at spots where the tin plating has been imperfect

and where the metal has been fractured by the die or double seamer. The maximum activity occurs at the surface of the liquid. In this case lacquer lining aggravates the trouble as fractures occur in the lacquer which in turn aid in concentrating the chemical action upon a small area.

Flat Sours.—The flat sour is a result of undercooking or lack of cooling. The organisms present develop without the production of gas but do develop a certain amount of acidity and thereby give rise to the name, flat sour. Hominy is an exception and in this product a sweetish taste is developed. The conditions may be caused by either heat-resistant organisms or thermophilic forms. The greater number of cases are credited to the latter, owing to insufficient cooling and stacking the cans in the warehouse while hot. There is nothing in the external appearance of the can to indicate that anything is wrong. Shaking may disclose somewhat more liquid contents than normal and cans placed in warm water will have the ends distended more quickly and upon cooling will collapse less readily than normal. Advantage was taken of this fact to make a separation of the bad from the good cans when that trouble was more prevalent than it is at present. Flat sours are more apt to occur in the interior of stacks of canned food than in the outer rows of cans. The remedy is to use an ample cook followed by prompt and efficient cooling, and the latter factor cannot be urged too strongly as it is effective and may also save the product from the resultant overcooking.

Stack Burning.—Stack burning is the result of storing cans while too warm thus holding the heat for several days, depending upon the mass. The contents soften sometimes to the point of becoming soupy, darken in color, and acquire a disagreeable flavor. The cans look galvanized or become a dull leaden color on the inside. Stack burning probably occurs more often in tomatoes than in any other product, owing in part to the fact that tomatoes do not resist heat to the same extent as most other products, and to the further reason that they are packed in large quantities and often stored without cooling, or care to leave narrow ventilating aisles between the double tiers. Peas become mushy and acquire a scorched taste with dark and starchy liquor. Other fruits and vegetables behave in a somewhat similar manner. Stack burning, like flat sours, occurs on the inside of stacks and not in the outer rows.

Effects of Freezing.—While the effect of low temperature above the freezing point is beneficial, freezing has always been avoided as far as possible. It is not considered particularly detrimental to most products provided that thawing takes place slowly. Freezing of soft fruits, such as berries and tomatoes, causes the tissues to become flabby and this is particularly noticeable when the products are shipped and handled. Some vegetables acquire a water-logged appearance and in others there is separation of liquid.

Metal containers accommodate themselves to the expansion of the contents upon freezing when not too severe, but glass is almost certain to break.

The first experimental work covering this phase is summarized in the report of the Secretary of the National Canners Association for 1931 (The Canning Trade, Feb. 9, 1931, page 28). It is as follows:

Effect of freezing on the quality of canned foods.

Twenty-nine canned foods have been frozen under known conditions and careful observations made on the effect of freezing by comparing the thawed product with control cans that had not been frozen.

The canned foods tested were blueberries in water and in sirup, cherries, grapefruit, peaches, pineapple, prunes, asparagus tips, baked beans, green beans, lima beans, whole-grain corn, peas, pumpkin, squash, spinach, tomatoes, chipped beef, corned-beef hash, Vienna style sausage, sausage with cereal, tongue, tripe, deviled ham, chicken in gelatin, chicken à la king, evaporated milk, sardines in oil, and spaghetti with tomato sauce.

None of the canned fruits tested was noticeably affected. Of the canned vegetables, asparagus, string beans, and pumpkin were seriously damaged. The consistency of the tomato sauce on baked beans was destroyed by freezing. The strands of spaghetti were broken down and the smooth consistency of the sauce destroyed. Of the meat products, corned-beef hash was very noticeably affected by the freezing, being also made granular and spongy. The sauce in chicken à la king was also made granular and spongy. Evaporated milk was curdled by freezing. Because the canned foods that contained cooked starches were seriously affected by freezing, a further study will be presented in the annual report of the research laboratories.

Discoloration.—Discoloration may be due to the effect of various metals upon the food substance, to the effect of high or prolonged heating, or to bacterial action. The discoloration due to the first cause is the best known and of the greatest concern.

Discoloration due to metals may occur from contamination before the foods are placed in the can or to a reaction between the food material and the container. Discoloration from without is well illustrated by the general blue-gray effect which occurs in corn when the machinery is first started in operation. Contact with copper at any point along the line of operation, and particularly at the filling machine causes darkening of grains and liquor. The same factor causes blackening of peas, so that copper is no longer regarded as suitable to be used in the equipment which comes in direct contact with certain foods. When used, it should be well tinned. Blackening of hominy, however, is most often due to failure to remove the lye rather than to any effect from the machinery. Recent experiments show that copper increases a distinct darkening effect upon milk.

The effect of iron upon fruits is such that it makes it undesirable to use any more of that metal in the apparatus than is necessary. Fruit juices are so sensitive to metals that most of them form lakes so that their preparation is best carried out in glass-lined kettles or porcelain-lined tanks. Some of the newer alloys such as stainless steel are especially desirable for use on preparation tables and where the fruits may be held for a short time. The effect of tin is nearly nil and no different from that in the container and any other vessel so there is no logic in turning the contents out of the can into another vessel.

Discoloration from the action of the food upon the container during cooking is a source of annoyance. A temperature of 245°F. or above breaks up some of the sulphur compounds in the proteins and these combine with the iron to form the black sulphide of iron. This is especially objectionable in corn. A black deposit forms in the headspace of the can and more or less of it becomes detached and mixed with the corn. It has been the subject of much study, but thus far without a wholly satisfactory preventive treatment. The closest approach is by the use of an inside lacquer which contains a trace of a zinc compound with which the sulphur may combine more readily than the iron. The zinc sulphide being white does not attract attention. It occurs in canned shrimp, lobster, crab, white meats from fish, and the meats from the slaughterhouses. It produces no harm except the objectionable appearance. In the case of shrimp, etc., liners of parchment paper or other protective material were used to prevent the meats from coming in contact with the metal and these measures afforded some relief. These liners have also been at fault in that sulphur compounds have been liberated, but their place has been taken by others not having such faults.

The bleaching effect upon the foods, especially those which are highly colored, may be overcome in a large measure by the use of inside-lacquered tins.

Discoloration due to heat is most often that of a darkening, though in the case of pears a distinct pink color may develop. Discoloration due to a leak is always one of darkening. Discoloration from bacterial action is rare, but is seen in peas, beans, corn, and fish products, and is almost invariably a blackening.

Foreign Flavors.—Foreign flavors are most often acquired before the foods are placed in the cans. Vegetables take on an acid taste owing to incipient fermentation. They also develop a bitterness owing to changes within their structure. This is more noticeable in asparagus than in most other products though it is not infrequent in corn and string beans. Fruits, as peaches and apricots, acquire a flavor from standing too long in pine lug boxes. It is difficult to describe but is referred to as piney, a slight suggestion of wood, turpentine, or resin. Fruits which stand in

cold storage develop a musty taste, even though no evidence of mould is present. Standing in a close, unventilated room, either cold storage or hot, develops a peculiar flavor the exact cause of which is not known. A flavor of carbolic acid is not uncommon in cans which have been marked with opaque ink if the marking has been done before the covers are attached. Recent experiments have shown that a carbolic or phenol taste may be developed in fruits of moderate acidity if the cans are marked with ink just before going into the exhaust box, but marking, either done upon the side of the can or on the cover, produces no effect if the ink is permitted to dry before entering the exhaust. Fruit standing near the inking device in the open develops only a trace of flavor, whereas that in the steambox becomes strongly impregnated if one or two drops of ink are placed on a cover and passed through in the regular line. The exposed top piece only is affected at first, but the flavor diffuses throughout the can in time. The flavor is most pronounced in heavily siruped fruit and not noticeable in light-sirup or acid grades. The best preventive for the trouble is to use an ink free from phenols. Somewhat similar flavor troubles have come from the use of water contaminated with waste from gasworks. Inside-lacquered cans have given objectionable flavor to asparagus, beans, and some other vegetables when the coating was not properly prepared. A similar mishap has occurred from the use of sealing compounds and gaskets for jars.

Sampling and Routine Testing.—A cannery, whether it is large or small, should make provision for the proper examination of its samples and output. Very much can be done with simple equipment and without technical skill. Each sample should be examined critically and a complete record made so that the effects of any changes may be determined by facts and not as a matter of opinion.

If a special room cannot be secured, then a table fitted with proper appliances should be set aside for the purpose in the factory.

The first requisite is a book in which to keep the records, giving the date of examination, name of the product, size of the can, code mark, gross weight, net weight, weight of solids, count of pieces where that is a factor, the condition of the solids, weight of sirup or brine, condition of the sirup or brine, Balling reading on the sirup or degree on the salinometer for the brine, grade of the pack, defects due to the raw material, preparation, or cooking. Whether all the tests are made or not, the record should be complete for those which are made. It affords the only means of knowing whether the packing is being done uniformly and whether or not improvement is being made.

Flat oval or oblong white-enamel pans or dishes are needed to receive the sample, and no matter what style is adopted they should be alike in size and shape so that each sample may be presented uniformly.

A good can opener is the most important single tool. There is little preference as to top or side opening types except that less juice is spilled when opening from the top.

A fairly sensitive balance or scale is another important article and it is better that it be graduated in both avoirdupois and metric units. The avoirdupois weights are the ones recognized as standard and used in the enforcement of the net weights under the Food and Drugs Act and, therefore, are necessary. The metric weights are much simpler for records and for computing percentages.

Screens with ¼-in. mesh and at least two with ⅛-in. mesh are needed for draining, according to the official methods. Several of the products are required to be poured upon a screen of ⅛-in. mesh and 8 or 12 in. in diameter, and allowed to stand 2 minutes in order to get the drained weight of solids. One colander with holes not larger than $\frac{3}{16}$ in. is also required. A clock with a second hand is advantageous in connection with the drainage tests.

The sirup is tested by means of a Balling or Brix spindle, otherwise known as a saccharometer. This gives the degree of the sirup in terms of the percentage of the sugar present in the straight sirup or more correctly speaking in terms of the percentage of sugar and soluble solids present in the sirup in the can after processing. Some of the soluble solids from the fruit go into the sugar and cause some variation but not enough to affect in any marked degree the relation between the original sirup used and that found in the cutout.

The testing of brine is done in the same manner as testing sirup but with a salinometer, each degree on the latter corresponding to 0.25 per cent of salt.

The testing of products for sterility, though important, is not carried out in many canneries, owing to lack of bacteriological apparatus and trained persons capable of conducting such laboratory procedure. The more progressive organizations have come to realize that the maintenance and support of such laboratories is a worthwhile investment. Others depend upon published data concerning time and temperature for sterilizing their products and trust to fate that the heat treatment as used has accomplished the desired purpose.

Certain information may be obtained in a practical way by the examination of products which have been placed in warm rooms or incubators. If cans are placed at a temperature of about 100°F., evidence of swells due to insufficient cooking or leaks may be obtained, generally within a few days. One may obtain evidence concerning the development of flat sours within a period of two weeks by the use of an incubator maintained at about 130°F., which is favorable for the growth of the thermophilic bacteria.

The holding of cans at high temperatures also affords information regarding springers from overfilling or lack of proper exhausting. By continued storage at these temperatures one may obtain some indication of the progress of changes between product and container which may result in springers, especially in acid foods.

Incubation tests are now a part of the routine in the bacteriological testing of foods and were first recommended by Prescott and Underwood about 1898. From the plant standpoint, incubator tests enable those in charge of a cannery to modify cooking operations if conditions arise which indicate that it is necessary. In instances where doubt is expressed as to sterilization, recooking may be carried out as a safety measure.

TABLE 101.—RELATION OF STEAM PRESSURE AND RETORT TEMPERATURES

Gauge Pressure, Lb. per Sq. In.	Temperature, °F.
0 (14.7 atmospheric)	212.0
1	215.2
2	218.3
3	221.3
4	224.2
5	226.9
6	229.5
7	231.9
8	233.3
9	236.6
10	238.8
11	241.0
12	243.0
13	245.3
14	247.3
15	249.1

The rate of heat penetration is so important a factor in sterilization that tests of that nature are needed at intervals, especially whenever there is an appreciable change in the character of the raw product. Cans having special caps can be secured so that self-registering thermometers may be sealed in place and the temperature obtained in the exhaust box or cooker. Such tests will show only the maximum degree attained but not the duration of the highest temperature. The simplest apparatus that will tell the story of heat penetration in a product and which can be used by anyone consists of a can with a screw head or opening into which a stuffing box can be fitted. The stuffing box is made for the insertion and protection of a special thermometer which will permit the bulb to be inserted to the center of the can or slightly below and have the graduation for reading on the outside. The can may be heated in a bath with water, brine, oil, or other liquid raised to the same temperature as used in the

TABLE 102.—CANS FOR FRUITS AND VEGETABLES

A general conference of representatives of can manufacturers, canners, canned-food distributors, and others interested drafted, on Jan. 20, 1931, a simplified practice recommendation covering the stock sizes of cans for fruits and vegetables, as well as the nomenclature applying to these cans. The industry has since accepted, and approved for promulgation by the U. S. Department of Commerce, through the National Bureau of Standards, the following simplified schedule of sizes:

Over-all dimensions, in., sealed can		Can maker's description	Capacity, oz. avoir. of water at 68°F., full can, sealed	Name
Diameter	Height			
2 2/16	2 14/16	202 by 214	4.85	5Z.
2 2/16	3 8/16	202 by 308	6.08	6Z.
2 8/16	2 11/16	208 by 211	6.01	Baby
2 11/16	3	211 by 300	7.93	8Z short
2 11/16	3 4/16	211 by 304	8.68	8Z tall
2 11/16	4	211 by 400	10.94	Picnic (No. 1 eastern)
2 11/16	4 8/16	211 by 408	12.45	3/4 pint
2 11/16	6	211 by 600	16.98	Pint
3	4 7/16	300 by 407	15.22	No. 300
3	4 9/16	300 by 409	15.69	No. 300X.
3 1/16	2 8/16	301 by 208	8.23	No. 1 flat
3 1/16	4	301 by 400	14.02	No. 1 short
3 1/16	4 11/16	301 by 411	16.70	No. 1 tall
3 3/16	4 6/16	303 by 406	16.88	No. 303
3 7/16	2 4/16	307 by 204	9.21	No. 2 flat
3 7/16	3 2/16	307 by 302	13.50	No. 2 squat
3 7/16	4	307 by 400	17.79	No. 2 short
3 7/16	4 8/16	307 by 408	20.25	No. 2 special
3 7/16	4 9/16	307 by 409	20.55	No. 2
4 1/16	2 5/16	401 by 205	13.38	No. 1 1/4 special
4 1/16	2 6/16	401 by 206	13.81	No. 1 1/4
4 1/16	4 11/16	401 by 411	29.79	No. 2 1/2
4 4/16	4 14/16	404 by 414	35.08	No. 3
6 3/16	7	603 by 700	109.43	No. 10
6 3/16	8 12/16	603 by 812	138.34	Full gallon
3 by 3 8/16	3 8/16	300 by 308 by 308	17.27	No. 1 square
3 by 3 8/16	6 4/16	300 by 308 by 604	32.47	No. 2 1/2 square

This recommendation, subject to regular revision by a standing committee of the industry, was made effective Sept. 1, 1934.

regular cooker. The temperature may be read directly at such intervals as may be desired. It is not the best method but it is practical and inexpensive. Electrothermocouples are available for laboratory workers, but they are too delicate for ordinary use.

Testing for vacuum is done most readily with a Young vacuum gauge. It gives the information with the minimum of trouble. Sometimes it is desirable to set the cans in a bucket of warm water, about 95°F. or the temperature approximating that of the place to which the foods are to be shipped, in order to simulate the conditions to which they will be exposed.

A pressure tester is not so important but is well worth using in connection with the adjustment of double seamers. The can caliper, three-cornered file, and pliers for cutting and tearing seams are also part of a good equipment. They are used in locating trouble from cans and the sealing operations.

NOTE. In March, 1937, Dr. Bitting's new book, "Appertizing, or The Art of Canning; Its History and Development," was published through The Trade Pressroom, San Francisco. This truly cyclopedic volume, which presents an excellent history of the art, and reproduces some of the original papers in full, deals with especial thoroughness and detail with the uses of the manifold canned products, the actual operations employed in their production, handling and sterilization, and with the varied methods of standardization, labelling and packaging for the market. The food manufacturer and the food technologist will find the volume a veritable mine of information.—THE AUTHORS.

CHAPTER XV

REFRIGERATION

The preservation of foods by the use of low temperatures has been recognized and appreciated by man for many centuries. The use of caves, holes dug in the ground, and the cool water in wells, springs, streams, and the like, as a means of lowering the storage temperature has served for many years to benefit man because such storage in the warmer seasons of the year tends to preserve or lengthen the life of perishable foodstuffs. Such utilization of nature's resources is far from uncommon, even today, in the rural districts where other means of refrigeration may be lacking. Probably the best example is the storing of milk in containers lowered into wells and springs containing relatively cold water.

Doubtless during the more primitive ages of man no great efforts were made to utilize nature's refrigerants, but it is said that Marco Polo returned from his famous travels in the East during the thirteenth century bringing back reports of the use of ice for chilling certain types of foods. The same methods were reputed to have been common in the East for a number of centuries previous to that time. The Romans valued ice and snow as a means of cooling and preserving foods and transported them from countries of the North especially for this purpose. One of the earliest articles of export from New England was ice, harvested during the winter season from the surface of frozen fresh-water ponds near the seaports of Massachusetts, such as Wenham Lake near Salem, and shipped to the West Indies in vessels which on their return trip brought cargoes of tropical products.

Those foods which require lowered temperatures for their proper preservation are much more common in this country today than was the case a generation ago, largely because facilities have become available for the storage and transportation of such foods. The rapid development of mechanical refrigeration in recent years has had marked influence on our agriculture, because without refrigeration many products now raised in large quantities could not be kept long enough to be utilized by the consumers who might live some hundreds or even thousands of miles distant. Numerous foods are now available in their fresh form the whole year round which were formerly unseen except during their relatively short growing season in each region.

The construction of cold-storage warehouses is of comparatively recent origin, the first one in America having been erected in New York

in 1865. Since this time, and particularly since 1890, there has been a tremendous impetus to this huge industry which has grown so that there are now some 1,400 cold-storage warehouses in the United States which are capable of handling a million carloads of refrigerator freight a year.

Many of these warehouses are located at strategic points in the larger cities where they are easily available to rail transportation and trucking facilities. In the seaboard cities they are often adjacent to the piers in order to accommodate water shipments with a minimum of handling and truckage. They may also be found near large packing plants, fruit-shipping points, terminals, dairies, ice-cream plants, and numerous other food industries handling perishable materials. To conserve losses in refrigeration, many types and designs of construction are to be found, all of course highly insulated, but differing widely according to particular needs for refrigerating facilities which have developed in specific locations.[1]

In addition to the commercial refrigeration plants, the need for proper refrigeration of foods has been clearly appreciated by the populace by use of ice-boxes, and especially in the past decade when several million domestic mechanical refrigerators have been annually installed in homes to complete the careful handling of foods from the producer to the consumer. These have provided a valuable service in the interests of both health and economy.

FUNDAMENTAL CONSIDERATIONS

The fundamental reason for the preservation of foods at low temperatures is to prevent spoilage or decomposition and those deleterious influences which accompany such changes. These decomposition processes are due to two factors, one of which is the biochemical activity of those microorganisms present in foods. The other factor is the biochemical change brought about by enzymes or chemical agencies normally present in the foods themselves owing to the fact that they are of plant or animal origin. The latter changes are frequently called "autolytic."

Both of these types of changes which occur in foods may be retarded by lowering the temperatures. This lowers the rate of growth of the microorganisms and also decelerates the rate of chemical or enzyme action due either to bacterial enzymes or to food enzymes. Thus the maintenance of refrigeration temperatures, by inhibition of bacterial or fungous development and the biochemical activities which are closely associated, tends to prevent rapid-change decomposition.

[1] For information concerning the many phases of the engineering aspects of cold storage the Refrigeration Data Book of the American Society of Refrigerating Engineers is a most helpful reference.

The numbers of bacteria present in foods and food products and the chemical activity brought about in these foods owing to microorganisms are closely related. The more numerous the bacteria the greater are the changes. Small numbers of bacteria, even a few hundred per gram, will cause only slight change from a chemical standpoint, but it must be remembered that unless the temperature of storage is kept low, the hundreds of bacteria will become millions in a few hours. With such bacterial populations present, the quality, chemical composition, tastes, and odors of foods may be expected to change markedly in short periods of time.

The types of bacteria present in foods are also of considerable significance. Bacteria vary greatly, both in their chemical activities and in reaction to temperature conditions. Some grow best at relatively high temperatures, *i.e.*, well above human body temperatures. Others develop best at relatively low temperatures and may be able to grow at temperatures even below the freezing point of water. Between these two groups is another, much larger and probably of greater importance from the food standpoint, because it contains a large majority of those many types of bacteria which can carry on their activities within temperature limits of approximately 50 to 100°F. It is the latter group which play the most important part in food spoilage of the common types. The temperature limit of these various groups is arbitrary and unimportant. The fact that low temperatures restrict the activities of many of these organisms is, however, of great significance.

In addition to the physiological effect of cold in retarding growth of bacteria, there is another factor involved, namely, that of food supply. These microorganisms require nutriment for their growth as do all other plants, and a moist environment is essential for their normal metabolic activities because all their food materials must be in a liquid form in order to permeate their cell walls or membranes. If the storage temperatures are sufficiently low to bring about the crystallization of water, which is a major constituent of many food products, the remaining constituents of the food are concentrated in the water left in the liquid state, but eventually the bacteria are restricted in their normal processes because of the low concentrations of water and the resultant high concentrations of other materials in solution or colloidal suspension. This consideration applies particularly to frozen foods which will be discussed subsequently.

Under conditions of low-temperature storage the so-called respiration of many plant products is retarded. The respiration or interchange of gases which is coincidental with the ripening or maturation processes of plant tissues, even though they may be removed from the field, may thereby be controlled in such a manner that the food reaches its optimum

state of maturity at the desired time. This is particularly essential in respect to fresh fruits which are transported and sold as such.

Any attempt to estimate the savings and conservation of food supplies which have been made possible through the use of refrigeration would be difficult, but the magnitude of such savings is tremendous from the standpoint of both material and value. Not the least in importance in this respect are those savings from a health standpoint which have resulted from the increased use of proper refrigeration. The transmission and incidence of certain diseases have been unquestionably reduced, owing in part to the more common and intelligent use of refrigeration in recent years.

The economic advantages of food refrigeration are manifold. Besides saving that part of the food material which might otherwise have been subject to spoilage, there are other and probably greater economic savings derived by refrigeration. Most of our food materials have a seasonal peak of production, such as is the case with potatoes, apples, tomatoes, also with eggs, milk, and certain types of fish. At the time of these peaks of production the supplies of these materials are large, the markets sometimes glutted, and the prices at this time are low. In many instances the periods of greatest demand do not coincide with the peaks of production. By refrigeration it is possible to store food material from the period of excess production and preserve it in a satisfactory manner until those periods when the normal supply of the same commodity is low and the price higher. At this time the refrigerated foods are taken from storage and sold, at a price which is lower than the market price for the same product which is out of season, but at a higher price than could be obtained at the time when the food was produced, although the storage has not impaired the quality of the stored material in any respect.

The time when cold-storage goods were looked on with suspicion is rapidly becoming an era of the past. The prejudice against foods because they have been refrigerated is no longer justified because much more strict supervision is maintained over foods in cold storage than many which are sold in what is assumed to be a "fresh" form. It is possible to obtain some foods which have been refrigerated that are of equal or better quality than some foods of the same type which have not been subjected to refrigeration but have been carelessly handled or stored. From some standpoints, refrigeration, if properly conducted, may be considered the most desirable means of food preservation because those changes in flavor and taste which result from the other processes of preservation, such as dehydration, salting, smoking, and canning, are eliminated in refrigeration.

The length of time that certain foods are to be stored and preserved determines in part the temperature best suited for storage. Foods which

are to be used in a comparatively short time are in general stored at the higher temperature levels of refrigeration, while certain of those which are to be kept for several months are frozen rather than chilled.

The character of the food, its cellular structure, chemical composition and similar factors must be taken into consideration when the optimum conditions for refrigeration are to be determined. From a commercial standpoint, although it may be desirable to have optimum conditions of refrigeration available for all the types of food which may be refrigerated, it is necessary to adopt conditions which may be used with satisfactory results for certain groups of food materials, because the maintenance of a large number of different storage temperatures in a commercial cold-storage warehouse is sometimes both difficult and expensive. Therefore a compromise is necessary which will accomplish the maximum benefit for those materials which must be stored under the same general conditions.

NEED FOR CONSTANT TEMPERATURES IN STORAGE

In the cold storage of foods the maintenance of constant temperatures is also a factor of great importance. Especial attention in this respect must be paid to fruits and vegetables in storage because if the temperature varies even a few degrees Fahrenheit it may be sufficient to freeze the product, which in some cases may be disastrous. On the other hand, if a rise in temperature of the same extent occurs, it may seriously shorten the storage life of the product as the physiological processes of plants are accelerated under such circumstances.

During such metabolic processes heat is evolved by the plants and carbon dioxide is produced and liberated. The heat resulting from these vital processes which correspond to our own breathing must be considered, as it increases the refrigeration load. The quantity of heat evolved by different plants varies considerably. Lettuce, Bartlett pears, peaches, and cherries have particularly high respiration rates, and therefore cause greater increases in heat production or liberation, while potatoes, apples, and onions are comparatively low as heat producers. In order to maintain the same temperature in a storage place, it would therefore require more refrigeration for the former foods than for the latter. The higher the temperature of storage the more rapid the evolution of heat owing to plant metabolism, as is shown in Table 103.

In the transportation of foods in refrigerator cars and the holds of vessels this consideration is also of great importance and indicates the necessity of precooling cargoes of plant products before loading.

RELATIVE HUMIDITY A FACTOR IN PROPER STORAGE

Although temperature is the primary consideration in the refrigeration of foods, there are certain other factors which are of great importance.

TABLE 103.—APPROXIMATE RATE OF EVOLUTION OF HEAT BY CERTAIN FRESH FRUITS AND VEGETABLES WHEN STORED AT TEMPERATURES INDICATED*

Commodity	Temperature, °F.	British thermal units of heat per ton of fruit per 24 hours
Apples	32	660– 880
	40	1,100– 1,760
	60	4,400– 6,600
	85	6,600–15,400
Bananas:		
Green	54	3,300
	68	8,360
Turning	68	9,240
Ripe	68	8,360
Grapefruit	32	460
	40	1,070
	60	2,770
	80	4,180
Lemons	32	580
	40	810
	60	2,970
	80	6,200
	77	2,200– 3,300
Lettuce	32	638
	40	7,392
	60	22,660
Oranges	32	690– 900
	40	1,400
	60	2,170– 2,970
	80	8,000
Pears (Bartlett)	32	660– 880
	60	8,800–13,200
Strawberries	35	3,300
	60	13,200–15,400
	32	2,730– 3,800
	40	5,130– 6,600
	60	15,640–19,140
	80	37,220–46,440
Tomatoes (mature green)	32	0
	40	132
	60	2,574

* Taken from *U. S. Dept. Agr. Circ.* 278, 1933.

The relative humidity of the air in the storage warehouse or room is a factor of significance from both the practical and economic standpoint. At refrigeration temperatures foods will lose water owing to evaporation unless a sufficient relative humidity is maintained. As most foods are

TABLE 104.—PREFERRED AMERICAN STORAGE PRACTICE*

Product	Optimum conditions			
	Temperature, °F.	Relative humidity, per cent	Air circulation	Period
Apples..........	31–32	90	Yes	3–10 months, depending on variety
Apricots:				
Dried.........	31–32	60		
Fresh..........	31–32	90	Yes	12 months
Asparagus.......	32–34			1 month
Bacon:				
Fresh..........	0–5			
Smoked.......	31–33			
Beans (string)...	33–34		Yes	1 month
Beef............	0			
Beets...........	32–33		Yes	1 month
Blackberries.....	32–33			
Butter..........	0–5			12 months
Cabbage........	32–33			3 months
Cantaloupes.....	32–33		Yes	2 weeks
Carrots:				
Dry..........	32–33		Yes	3 months
Iced..........	31–32		Yes	1 month
Cauliflower.......	32–33		Yes	3 weeks
Caviar:				
Pressed salted..	31–32			
Fresh..........	26–28			
Celery...........	32–33	95		3 months
Cherries..........	32–33			
Cheese:				
Swiss..........	38–40			8 months
Roquefort......	38–40			8 months
American......	34–35			8 months
Cream.........	31–32			
Ricotto........	31–32			
Chestnuts........	31–32			6 months
Chocolate candies	45–50			
Cranberries.......	32–33			1 month
Corn, green......	32–33			
Cream, frozen....	0			4 months
Cucumbers.......	40			10 days
Currants.........	32–33			
Eggplants........	33–35			10 days
Eggs:				
Crated.........	30–31	84–86	Yes	10 months
Canned........	0–5	.....		12 months
Figs, dry.........	32–33	60		12 months
Fish:				
Fresh..........	0			
Frozen.........	0–10			
Gooseberries......	31–32			
Grapefruit........	32–33	85	Yes	3 months
Grapes...........	31–32	85	Yes	2–4 months, depending on variety

* Taken from Refrigerating Data Book, 1932–1933, by courtesy of the American Society of Refrigerating Engineers.

TABLE 104.—PREFERRED AMERICAN STORAGE PRACTICE.*—(*Continued*)

Product	Optimum conditions: Temperature, °F.	Relative humidity, per cent	Air circulation	Period
Hams:				
Fresh	0			
Smoked	31–32			
Hogs:				
Fresh	0			
Smoked	31–32			
Holly				
Honey	31–32			
Kohlrabi	32–33		Yes	
Lamb, frozen	0			
Lettuce:				
Dry	32–33			1 month
Iced	30–31			1 month
Livers	0			12 months
Malt	34–35			
Maple sirup	31–32			
Meat, salt	31–32			
Melons	31–32		Yes	6 weeks
Mushrooms	31–32		...	12 months
Nuts, dried	31–32		...	12 months
Oleo	34–36			
Onions	33–34		Yes	
Oranges	32–33	85	Yes	3 months
Oysters				
Parsnips	32–33			
Peaches	32–33		Yes	1 month
Pears	31–32	90	Yes	3–8 months
Persimmons	31–32		Yes	1 month
Plums	31–32		Yes	2 months
Pork:				
Fresh	0			
Pickled	31–32			
Potatoes:				
Irish	38–40			3 months
Sweet				
Poultry	−5 to −10 to freeze 0 to −5 to carry			12 months
Prunes, dried	31–32	60		12 months
Rabbits	0			12 months
Radishes	31–32			
Raisins	31–32			
Raspberries	32–33			10 days
Salmon:				
Barreled	31–32			
Fresh	0			
Sausage:				
Smoked	31–32			12 months
Casings	31–32			
Strawberries	32–33			
Turnips	31-32			
Yeast	31–32			

* Taken from Refrigerating Data Book, 1932–1933, by courtesy of the American Society of Refrigerating Engineers.

sold on a weight basis, such losses are direct losses incurred by the owners of the food products, and every effort is made to minimize this type of loss. Loss of water also causes wilting of vegetables and shrinking and drying of fruits. The humidity necessary for different foods varies, but in general the foods with the higher moisture contents require elevated relative humidities for optimum conditions.

Although from the standpoint of avoiding moisture losses it is desirable to have high storage-air humidities with certain types of refrigerated foods, such conditions are particularly favorable for the rapid growth of bacteria and molds which cause trouble with many foodstuffs, particularly fruits, vegetables, meats, and eggs. Therefore the humidity conditions which are used in most commercial refrigerated storage are compromises in an effort to keep spoilage at a minimum with due regard taken to the inevitable shrinkage and weight losses which must occur. The temperature level is also important in this respect because the lower the temperature, the more shrinkage is likely to result.

These same considerations are of particular importance in the handling and display of meats in stores where the changes which occur in meats at the higher temperatures and at the higher humidities definitely limit the length of time the food may be kept previous to sale.

Tables 106 and 107 include the temperatures and humidities advocated by the U. S. Department of Agriculture for the holding of various foods in commercial refrigeration. Individual practice in various warehouses depends upon the opinions of those who have had experience in respect to those types of commodities, or the stated desires of those who are paying for storage, and may vary considerably. The preferred storage practice, as advocated for certain of the more commonly refrigerated foods by the American Society of Refrigerating Engineers, is shown in Table 104. For more complete information along these lines the reader is referred to the Refrigerating Data Book and Catalog published by the above-named society. For modern German storage practice see Tuchschneid.[1]

From a practical standpoint, efforts are made to control the relative humidity of air in the cold storage of only a few products. The leafy vegetables which are among those foods having very high water content are kept at high humidities to prevent excessive losses. Many warehouses have separate rooms or buildings for eggs because of their exacting humidity requirements.

Marked changes in humidity as well as changes in temperature during storage are undesirable because the result is likely to be the precipitation of moisture on the product or "sweating," a condition which acceler-

[1] TUCHSCHNEID, M. W., Die Kaltetechnologische Verarbeitung schnellverderblicher Lebensmittel. Übertragen und neu bearbeitet von E. EMBLICK. 1936.

TABLE 105.—STATE LAWS CONCERNING COLD STORAGE*

State†	Authority	Warehouse definition	License requirements	License fee (annual)	Foods included	Inspection conditions	Records required	Storage marking required	Storage limit required	Transfer restrictions	Sales restrictions	Special state provisions
Alabama	Dept. of Agriculture and Industries Montgomery, Ala.	None	None Req.	......	......	......	......	......	......	......	(a)	(a) Cold-storage eggs must be so labeled.
Arizona	State Board of Health Phoenix, Ariz.	None	None Req.	......	......	......	......	......	......	......	(a)	(a) Eggs in cold storage for 3 months or more shall have the time in storage marked upon container. Sign "Cold Storage Food Sold Here" shall be displayed in salesroom.
California	State Board of Health San Francisco, Calif.	A-1,(a)	B	(b)	C,(c)	D	E	F	G	H	I,(d)	(a) Does not include home, hotel, restaurant, or exclusively retail establishment. (b) Plants 10,000 cu. ft. or less......$15 Plants 10,000 to 50,000 cu. ft....$30 Plants 50,000 to 100,000 cu. ft..$40 Plants over 100,000 cu. ft.......$50 (c) Also fresh fruits and vegetables, and cheese. (d) "These are cold storage goods" must appear on goods in letters 2 in. high, except where quality standards have been established by the Board, in which case the latter must be indicated.
Connecticut	Dairy and Food Commission Hartford, Conn.	None	None Req.	......	......	......	......	......	......	......	(a)	(a) Eggs in storage with refrigeration for 15 days or more shall have "Cold Storage Eggs" on crate in 2-in. letters. Bags or containers shall have 1-in. letters on 2 sides.

Delaware...........	State Board of Health Dover, Del.	None	None Req.	......	C-1,(a)	D	E	......	G	......	(b)	(a) Except fish and fruit. (b) Sale of cold-storage undrawn poultry prohibited; eggs must be sold from original crate bearing date of storage.
Florida.............	No regulative cold storage laws (a)	......	......	......	......	......	......	......	......	......	......	(a) A law provides for erection and operation of publicly owned cold-storage plants, half the funds to be provided by the county and half by the State.
Georgia.............	Food and Drugs Department Department of Agriculture Atlanta, Ga.	None	None Req.	......	......	D	(a)	......	......	......	(b)	(a) List must be kept of all eggs, date of receipt and withdrawal and to whom delivery is made. (b) Eggs must be labeled and placarded "Cold Storage Eggs."
Idaho...............	Department of Public Welfare Boise, Idaho	None	None Req.	......	......	......	......	(a)	......	......	......	(a) All butter placed in storage shall have stamped on each container "Cold Storage Butter" and date when stored, in solid black type.

UNIFORM PROVISIONS OF COLD STORAGE LAWS

* Taken from *Food Ind.*, pp. 226–228, May, 1931.

† Arkansas, Colorado, Kansas, Maine, Mississippi, Missouri, Nevada, New Mexico, North Carolina, Oklahoma, South Carolina, Texas, West Virginia, Wyoming and District of Columbia have no cold storage laws.

A. "Cold storage warehouse" is any place where articles of food are kept for more than 30 days at a temperature of 45°F. or below supplied by refrigeration.

A-1. Same as above, but with 40°F. temperature limit.

B. License required by all cold-storage warehouses. Issued annually after examination indicates satisfactory sanitary conditions. Revocable upon due notice if violations develop.

C. "Articles of food" means fresh meat, fresh-meat products (except in process of manufacture), fresh fish, game, poultry, eggs, and butter.

C-1. "Articles of food" means any food, drink, or condiment consumed by man (except in process of mfg.).

D. Access to plant at any time must be accorded properly designated state authorities for inspection of plant and records.

E. Accurate records showing receipts, withdrawals, and holdings must be kept accessible to inspectors at all times. Quarterly reports of holdings must be submitted to state authority.

E-1. Same as above, but *monthly* reports are required.

F. Article or container must be plainly and permanently marked with date of entry and withdrawal. Material unfit for food must be so marked.

G. No food shall be kept in storage longer than 12 months, except when an extension is granted after inspection by state authority.

H. Return of articles removed for sale to cold storage is unlawful.

Transfer from one warehouse to another is permitted when it does not involve evasion of law.

I. Articles of food, when offered for sale, must be marked to indicate that they are cold-storage goods by placard on the bulk mass of articles. Unlawful to represent them as fresh.

I-1. A placard "Cold Storage Food Sold Here" must be displayed by those handling such products. Unlawful to represent such goods as fresh.

TABLE 105.—STATE LAWS CONCERNING COLD STORAGE.—(*Continued*)

State	Authority	Warehouse definition	License requirements	License fee (annual)	Foods included	Inspection conditions	Records required	Storage marking required	Storage limit required	Transfer restrictions	Sales restrictions	Special state provisions
Illinois	Division of Foods and Dairies State Department of Agriculture Chicago, Ill.	A	B	$25	C	D	E-1	F	G,(*a*)	H	I	(*a*) Authorities may order removal from cold storage at any time for the following reasons: Fictitious price increase, monopoly, restraint of trade.
Indiana	Department of Foods and Drugs Indianapolis, Ind.	A-1	B	$10	C,(*a*)	D	E,(*b*)	F,(*c*)	(*d*)	H	I,(*e*)	(*a*) Also cheese, fruits, farm or garden produce or any other perishable foodstuff. (*b*) Periodic reports not required. (*c*) Markings must be in black or purple ink; letters 3/8 in. high. (*d*) All goods in storage for 9 months must be inspected and passed by state authorities before sale. (*e*) The wrapper, bag, or container in which eggs are delivered to customer must bear the words, "Cold Storage."
Iowa	Department of Agriculture Des Moines, Ia.	A-1,(*a*)	B	$25	C-1	D	E	F	G	H	I-1,(*b*)	(*a*) Does not include home, hotel, or refrigerator car. (*b*) Letters of sign must be 3 in. high and 2 in. wide.
Kentucky	State Board of Health Louisville, Ky.	None	None Req.	......	......	......	......	......	......	......	(*a*)	(*a*) An article of food is deemed misbranded if, when the length of time it has been stored tends to render it unwholesome, such aging or packing is not made known to the purchaser.

Louisiana............	State Board of Health New Orleans, La.	A-1	B	None	C-1	D	E	F	G	H	I-1	
Maryland............	State Board of Health Baltimore, Md.	A	B	$25	C,(*a*)	D	E-1	F	G,(*b*)	H	I	(*a*) Includes all fish. (*b*) Extension shall be for not more than 60 days. Second extension of 60 days may be permitted after re-examination, but no more than 120 days in all.
Massachusetts........	Department of Public Health Boston, Mass.	A	B	$10	C,(*a*)	D	E-1	F,(*b*)	G	H	I-1,(*c*)	(*a*) No fish shall be placed in storage that has not been graded No. 1 or No. 2. (*b*) But date of withdrawal not required. (*c*) No fish may be sold more than 48 hours after receipt from cold storage, unless received and sold frozen, except Nov. 1 to March 31. Halibut, salmon, swordfish and steak-cod may be sold one week after receipt if they remain frozen until 48 hrs. before time of sale.
Michigan............	Department of Agriculture Lansing, Mich.	......	......	......	......	......	......	......	......	......	(*a*)	(*a*) Eggs in storage at 40°F. or below for 30 days must be marked "Cold Storage Eggs."
Minnesota...........	Department of Agriculture St. Paul, Minn.	A,(*a*)	B,(*b*)	$50	C-1	D	E-1,(*c*)	F	G,(*d*)	H	I-1,(*e*)	(*a*) Except refrigerator cars or ships. (*b*) Schedule of rates must be filed and kept open for public inspection. (*c*) Uniform receipts required. (*d*) Same as (*b*) for Maryland. (*e*) Official placards, cancellable and not transferable, must be obtained from Dept. (Fee $0.50).
Montana.............	Department of Public Health Helena, Mont.	None	None Req.	......	......	......	......	......	......	......	(*a*)	(*a*) Cold-storage eggs must be so labeled.

TABLE 105.—STATE LAWS CONCERNING COLD STORAGE.—(*Continued*)

State	Authority	Warehouse definition	License requirements	License fee (annual)	Foods included	Inspection conditions	Records required	Storage marking required	Storage limit required	Transfer restrictions	Sales restrictions	Special state provisions
Nebraska	Department of Agriculture Lincoln, Neb.	(*a*)	B	\$5,(*b*)	C-1	D,(*b*)	E	F	G	H	(*c*)	(*a*) Keeping articles of food at 40°F. or below for 60 days. (*b*) Inspection fee of: \$10 for less than 50,000 cu. ft. \$25 for 50,000 to 100,000 cu. ft. \$50 for over 100,000 cu. ft. is required annually. (*c*) Purchasers must be notified that product is storage goods.
New Hampshire	State Board of Health Concord, N. H.	A-1	B	\$10	C	D	E	F	G	H,(*a*)	(*b*)	(*a*) No transfer permitted after 11 months storage except with extension granted by board. (*b*) Egg and poultry packages must be stamped "Cold Storage" in cap. letters not less than ⅜ in. square.
New Jersey	Bureau of Foods and Drugs Department of Health, Trenton, N. J.	A,(*a*)	B	\$10	C,(*b*)	D	E-1	F	G	H	I	(*a*) Does not include refrigerators maintained by wholesale or retail grocers. (*b*) Also edible fats, cheese and miscellaneous milk products.
New York	Department of Agriculture and Markets Albany, N. Y.	A,(*a*)	B,(*b*)	\$25,(*c*)	C-1,(*d*)	D	E-1,(*e*)	(*f*)	G	H	(*g*)	(*a*) Except for home use. (*b*) Financial responsibility also must be established. (*c*) Cold-storage warehouses handling fruits and vegetables exclusively, \$10. For each warehouse in excess of one, \$5. (*d*) No exception for process of mfg.

												(e) Confidential financial statements may also be required at any time. (f) Identification lot number. (g) Invoice must indicate storage.
North Dakota........	State Food Commissioner and Chemist Bismarck, N. D.	(a)	None	......	......	......	......	F	......	......	(b)	(a) Any place where food is artificially cooled to 40°F. or below, except private home, restaurant, hotel, or refrigerator car. (b) Cold-storage goods must be so labeled.
Ohio................	Division Foods and Dairies Department of Agriculture Columbus, Ohio	A-1	B	$50	C	D	E	F	G,(a)	H	(b)	(a) No provision made for time extension. (b) Each container of cold storage food shall be labeled "wholesome cold storage food" in letters at least ½ in. high. Placard with same legend must be posted.
Oregon..............	Dairy and Food Department Portland, Ore.	......	......	......	(a)	......	......	......	G	......	......	(a) Poultry, rabbits and fish.
Pennsylvania.........	Bureau of Foods Department of Agriculture Harrisburg, Pa.	A-1	B	$50	C	D	E	F	G,(a)	H	I,(b)	(a) No provision for time extensions. (b) "Cold storage goods" must also be stamped on retail wrapper.
Rhode Island.........	Food and Drug Commission Providence, R. I.	None	None Req.	......	......	......	......	......	......	......	(a)	(a) Eggs stored for 30 days at 40°F. or below are "cold storage eggs" and container must be so marked. Placard must appear in connection with display of such eggs in bulk.
South Dakota........	Department of Agriculture Pierre, S. D.	None	None Req.	......	......	......	......	......	......	......	(a)	(a) Cold-storage eggs must be so labeled.
Tennessee...........	Department of Agriculture Nashville, Tenn.	A,(a)	B	$10	C	D	E-1	F	G	H	I	(a) Does not apply to refrigerators of retail or wholesale grocers.

TABLE 105.—STATE LAWS CONCERNING COLD STORAGE.—(*Continued*)

State	Authority	Warehouse definition	License requirements	License fee (annual)	Foods included	Inspection conditions	Records required	Storage marking required	Storage limit required	Transfer restrictions	Sales restrictions	Special state provisions
Utah...............	Commissioner of Dairy and Food Salt Lake City, Utah	A	B	$10	C	D	E-1	F	G	H	......	
Vermont............	No cold storage laws	......	......	......	......	D,(*a*)	......	......	......	......	......	(*a*) Dept. of Public Health has right to inspect all places where food is made, packed, stored or sold.
Virginia............	Dairy and Food Commissioner Richmond, Va.	A,(*a*)	B,(*b*)	$25,(*c*)	C,(*d*)	D	E	F	(*e*)	H	I	(*a*) Does not apply to refrigerators of wholesale or retail dealers. (*b*) No public cold-storage warehouse charging for food storage shall directly or indirectly own or deal in food commodities stored in such warehouse except those legally acquired for charges. (*c*) Except when gross business is less than $1,000, $5; $1,000 to $2,000, $10; over $2,000, $25. (*d*) Also cheese, edible fats and oils and lard. (*e*) No food shall be kept in storage longer than 10 months, without consent of Commissioner. No cold-storage warehouseman shall loan or incur liability in connection with loans on food stored in such warehouse in excess of 70 per cent of the market value of such food.

TABLE 105.—STATE LAWS CONCERNING COLD STORAGE.—(*Continued*)

State	Authority	Warehouse definition	License requirements	License fee (annual)	Foods included	Inspection conditions	Records required	Storage marking required	Storage limit required	Transfer restrictions	Sales restrictions	Special state provisions
Washington..........	Division of Foods, Feeds, Fertilizer and Drugs Department of Agriculture Olympia, Wash.	None	None Req.	......	......	......	......	......	(*a*)	......	(*b*)	(*a*) Eggs in cold storage for more than 9 months can only be sold after obtaining permit. (*b*) Eggs in cold storage more than 90 days must be labeled "Storage."
Wisconsin............	Dairy and Food Commissioner Madison, Wis.	(*a*)	B	(*b*)	C,(*c*)	D	E-1	F	G,(*d*)	H,(*e*)	I	(*a*) "Cold Storage Warehouse" shall mean any place where foods are artificially cooled to or below 45° F., for 40 days or more. (*b*) In first class city, $40. In second class city, $30. In third class city, $20. In fourth class city, $10. (*c*) Also butter substitutes. (*d*) Extension shall not exceed 30 days. (*e*) Eggs and butter may be returned for further storage after examination if markings remain thereon.
Alaska..............	Office of the Auditor Juneau, Alaska	......	(*a*)	......	......	......	......	......	......	......	......	(*a*) License fees required as follows: For gross income of— $100,000 or more per year.....$500 $75,000 to $100,000 per year..$375 $50,000 to $75,000 per year....$250 $25,000 to $50,000 per year....$125 $10,000 to $25,000 per year....$ 50 $4,000 to $10,000 per year.....$ 25 Under $4,000 per year.........$ 10

TABLE 106.—RECOMMENDED TEMPERATURE, RELATIVE HUMIDITY, AND APPROXIMATE LENGTH OF STORAGE PERIOD FOR THE STORAGE OF VARIOUS VEGETABLES

Commodity	Temperature, °F.	Relative humidity per cent	Approximate length of storage period	Average freezing point, °F.
Asparagus	32	85–90	3–4 weeks	29.80
Beans:				
Green or snap	32	85–90	3–4 weeks	29.74
Lima	32	85–90	3–4 weeks	
Beets:				
Topped	32	90–95	1–3 months	26.90
Bunch	32	85–90	7–10 days	
Cabbage	32	90–95	2–4 months	29.57
Celery	31–32	90–95	2–4 months	29.73
Corn, green	31–32	85–90	4–8 days	28.95
Lettuce	32	85–90	1–3 months	29.20
Peas, green	32	85–90	1–3 weeks	30.03
Potatoes	36–50	85–90	3–5 months	28.92
Tomatoes:				
Ripe	50–55	80–85	7–10 days	30.38
Mature green	55–70	80–85	1–6 weeks	30.40

* Taken from *U. S. Dept. Agr. Bull.* 278.

TABLE 107.—RECOMMENDED TEMPERATURE, RELATIVE HUMIDITY, AND APPROXIMATE LENGTH OF STORAGE PERIOD FOR THE COMMERCIAL STORAGE OF FRESH, DRIED, AND FROZEN FRUITS, AND NUTS*

Commodity	Temperature, °F.	Relative humidity, per cent	Approximate length of storage period	Average freezing point, °F.
Apples	31–32	85–88	2–8 months	28.44
Cranberries	32–40	80–85	1–3 months	27.16
Grapes:				
Vinifera	30–32	80–85	4–6 months	24.60
American	30–32	80–85	3–4 weeks	28.16
Lemons	50–55	80–85	2 wks.–4 mos.	28.14
Oranges	32	80–85	1–2 months	†
Peaches	31–32	80–85	1–2 weeks	29.14
Pears	30–32	85–90	30–45 days	‡
Raspberries:				
Red	31–32	80–85	7–10 days	30.14
Black	31–32	80–85	7–10 days	28.76
Strawberries	31–32	80–85	7–10 days	29.93
Dried fruits	32–50	70–75	1–2 years	

* Taken from *U. S. Dept. Agr. Bull.* 278.

† The figures for oranges are Florida (Valencia) 28.26°; California (Washington Navel), 27.70°.

‡ The figures for pears: Bartlett, 28.46°; Winter Nelis, 27.25°; Anjou, 26.93°.

ates decay and spoilage owing to microorganisms. The removal of the refrigerated products from storage to higher temperatures has the same effect, and care should be taken to avoid undue sweating if possible.

When plant products are respiring, they give off carbon dioxide, a gas normally present in air in small concentration. If the concentration of this gas is increased to a considerable extent, it may cause undesirable results such as brown heart which occurs in apples for this reason. Under normal circumstances the air circulation necessary to maintain constant temperatures is sufficient to prevent any accumulations of this gas.

Opinions regarding the air flow in cold-storage warehouses are quite diversified. The difference in opinion extends from those who believe no air flow is necessary to those who consider high velocities desirable. Opinions concerning specific foods are likewise at wide variance. It is necessary in some warehouses to maintain some air change in order to keep the temperatures at a constant level so in some instances the flow of air or ventilation in storage rooms cannot be avoided. Scientific investigation along these lines would be fruitful from an economic standpoint because such widely varying practical applications as are now utilized cannot all be optimum conditions.

The actual distribution and location of materials in a storage room are important. Many food materials packed in boxes, crates, etc., are piled in rows and tiers in cold-storage rooms, with wooden laths or spacers between containers so that the proper ventilation and heat transfer may be permitted.

In the larger metropolitan warehouses the temperatures at several points in the various rooms are read and checked hourly by employees to guard against improper conditions of storage. Humidity determinations are made daily to determine the amount of moisture in certain of the warehouses, although automatic control of humidity is not commonly practiced. If the humidity gets too low, the floors may be sprinkled with water and in those rooms where high relative humidity above a certain point is not desired, as in egg rooms, the entering air may be dried to the necessary extent with calcium chloride.

Doubtless many foods would be preserved more satisfactorily at higher humidities than are now used if it were possible to check the development of microorganisms under such conditions. The possibilities of ozone in cold-storage rooms have been investigated in this respect and a few egg houses are said to be using this method. Ozone is not adapted for use, however, where foods containing fat are present because of its accelerating effect on those chemical changes of fats and oils which are oxidative in character and which may result in rancidity or off-flavors in the product. Egg yolks contain fats but are protected by the shell, the membranes, and the surrounding albumin. The ozone treatment is such that only

a few parts per million are introduced with the air entering the room and the dosage is given only periodically. This treatment is said to lower the incidence of molds and allow somewhat higher humidities than were formerly used in egg storage.

Much more scientific research has been conducted on the storage of foods at refrigeration temperatures from the standpoint of domestic refrigeration than with large commercial installations, although the factors to be considered are the same in general. With meat and other domestic food products the size of the cuts or the mass of material is much smaller than the sides and quarters of beef hung in commercial storage or the large quantities of other foods, and therefore the relations of surface area to volume differ, which would necessarily alter the changes due to weight losses.

The same factors which are essential in the proper preservation of plant foods at low temperatures, namely, microorganisms, temperature, relative humidity, and air flow, apply also to meats, fish, and dairy products. In addition, the possible reaction of food with the oxygen of the air is of significance because of the occurrence of oxidative processes, rancidity, and also color changes which may result with certain types of food.

Data in this field by numerous workers indicate that the lower temperature levels afford the best protection against deteriorative changes, and that increased humidity in general favors more rapid growth of microorganisms. Variations in temperature likewise cause acceleration because of the precipitation of moisture on food surfaces where the bacteria are often most numerous.

The type and extent of chemical changes brought about will depend in part on the numbers of bacteria or molds originally present and their types, as different bacteria have widely differing chemical actions. In general, however, these changes in meats are largely proteolytic in character, and cause degradation of the protein or nitrogenous compounds present in the material. With dairy products the changes may be to some extent proteolytic but are much more likely to be due to the action of bacteria on the carbohydrate of milk, which is lactose, or milk sugar. This type of change is generally designated as an acid fermentation or fermentative change in contrast to proteolytic or putrefactive changes. Changes are likewise possible, owing to yeasts and molds, but not to the same extent.

It was at one time believed that most animal tissues were free of bacteria previous to slaughter, but recent investigations along these lines indicate that such is not strictly the case. It is inevitable that the usual slaughtering operations, careful though they may be, will add other microorganisms to those originally present so there are always some

bacteria present as a nucleus for changes which must be avoided as far as possible. As has been stated previously, even a few microorganisms may give rise to vast numbers if not inhibited in their normal progress by low temperatures.

REFRIGERATION IN TRANSPORTATION

The handling of vast quantities of perishable foods in their journey from the producing areas to the consumer often requires refrigeration en route. Considerable amounts may go into cold storage at points along the way, but the deteriorative changes in foods caused by both enzymes and microorganisms will progress in transit unless the foods are refrigerated. Even winter shipments of some food commodities have ice packed along with the foods, although sent in refrigerated cars to insure a minimum of damage during shipment. Spinach and peas shipped from the Southwest often arrive in New England with the ice still unmelted which was added when the products were packed.

The most common means of transportation of perishable foods is by rail, although for shorter hauls trucks are becoming more widely used. For certain types of foods, especially those in international commerce, such as meats, the transportation must be by ship. Time is an important element in the handling of most of our perishable foods, and the railroads have provided facilities for the rapid transportation of such products. There are the milk expresses which have as their goal the rapid delivery of milk from the rural producing areas to the metropolitan districts with their enormous consumption, the fruit expresses, and even egg expresses which sometimes cover thousands of miles in a few days.

Refrigeration is necessary in the individual units of the conveyances handling perishables, whether they be ships, railroad cars, or trucks. Thus, there are somewhat different considerations involved in providing refrigeration for materials in transportation than is the case with a large permanent stationary plant where powerhouse, brine systems, etc., may be used in the same spot for years and definitely coordinated. Weight is a great factor in any transportation system; for example, if a railway locomotive is to be efficient in hauling pay freight, it must preferably have a minimum of refrigeration equipment, from the standpoint of both weight and space, as a part of its load.

It is also desirable that whatever type of refrigeration is provided for freight transportation, it should be capable of continuously delivering refrigeration service whether the vehicle is in motion or not.

Refrigeration Cars.—Most of the refrigerator cars now in use are constructed so that ice is the refrigerating agent used. They are well insulated, have double walls, and are frequently painted with light-colored paint to cause a minimum of heat absorption as the lighter

colored surfaces reflect both light and heat. Some of the more recent ones are painted with aluminum paint. The general plan is to have four ice bunkers at each end inside the car. These bunkers have drains on the bottom and are open at the top. Each bunker has a capacity of about 700 lb. of ice and therefore each car may have a total load of about 5,600 lb. of ice. The bunkers are usually refilled at least once in 24 hours, although the length of interval is largely dependent on weather conditions and the amount and type of food transported.

Unless the car has been precooled before loading with food one cannot expect a refrigerator car to be a refrigerator. In the early days of refrigeration transportation, relatively warm foods were sometimes loaded in iced but not precooled refrigerator cars and the result was more that

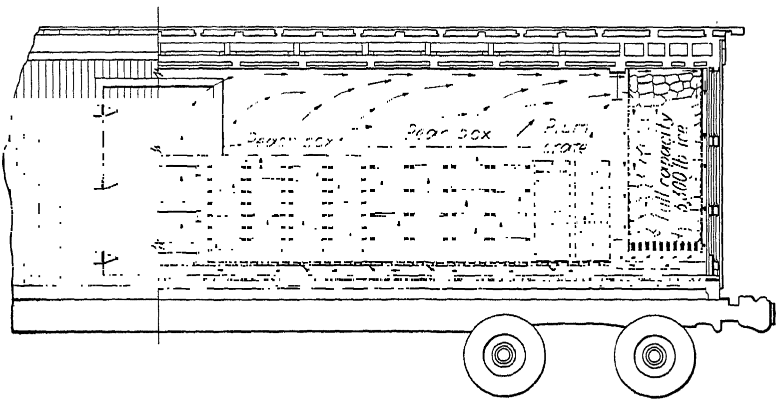

FIG. 59.—Section of refrigerator car loaded with fruit packed in containers of different shapes and sizes, showing the natural circulation of the air downward through the ice and upward through the fruit. (*Univ. California, Bull.* 496.)

of an incubator than what was expected. Just as a certain amount of melting ice is required to chill a car, definite amounts of refrigeration are needed to cool food products. Refrigerator cars are not generally designed to cool materials but rather to maintain them at low temperatures after they have been cooled elsewhere by other means. Therefore, practically all meats and many fruits and vegetables are precooled before loading in cars. The same is generally true of milk.

In some rural fruit- and produce-growing districts facilities such as cold-storage warehouses for the precooling of fruits are not available. Under such circumstances it has proved helpful to set up precooling systems whereby the cars themselves may be packed with fruit or other produce, and a portable type of forced-ventilation system installed which uses the ice in the ice bunkers as a means of cooling the contents. Moreover, the types of product and the loading or placing of the packages, as well as the wrapping and packaging of the product, influence the rate of

cooling to a marked extent. Those which are unwrapped or loosely packed allow convection currents and facilitate more rapid cooling. It is desirable to load the products during the hours when the products are cooler, *i.e.*, at night, in order to avoid extra refrigeration loads. It is calculated that such methods would reduce transportation costs and also keep the products under conditions best suited for the maintenance of high quality. Figure 59[1] shows the normal air currents which occur in a loaded refrigerator car containing fruits packed in containers of varying size.

The ice used in the bunkers is crushed to the size of 2- or 3-inch chunks and mixed with No. 2 rock salt. The ice should be free from foreign materials as otherwise the drains may clog. Larger-sized pieces of ice may be used but are likely to leave excessive voids while very small pieces pack too closely. Temperatures well below freezing may be maintained in cars by the use of ice and salt mixtures. It is said that by proper combination of the two components, temperatures from 20–30° below freezing may be attained but these temperatures are uncommon in use.

For proper refrigeration of the cargo the circulation of air is very important. Gravity is important in this respect because cold air from around the bunkers, which are elevated from the floor, displaces the lighter warm air which rises and eventually is diverted to the ice bunkers. Aprons are placed in front of the bunkers in order to govern the entrance of the air at the top and its exit at the bottom of the bunkers.

Many improvements in design, insulation, doors, floor racks, etc., have been made since the refrigerator car has come into use. Much study has been given to the proper placement of various foods and the optimum loading of cars. The larger packing companies which handle many types of foods have found that a definite arrangement of foods requiring somewhat different temperatures of storage may be accomplished satisfactorily in one freight car provided the location of each is predetermined by empirical tests and observations.

Sometimes refrigerator cars need to be heated, because in very severe winter weather the temperatures outside may be sufficiently low to damage the food materials. The cars are well-insulated and if a source of heat is installed below the ice bunker, it may be used to produce a uniform temperature. Certain cars have such a system using electrical resistance as a source of heat, permanently installed so that it may be used at any time. It is obvious that there would be no ice in the bunkers when the heat was to be used. The general course of the air flow or ventilation would be reversed under these circumstances.

[1] EVERHOLSER and MOSES, Pre-cooling of Fresh Fruits and Temperatures of Refrigerator Cars and Warehouse Rooms, *Univ. California Bull.* 496.

The Tank Car.—For many years fluid milk was transported in special refrigerated cars, the milk itself being held in heavy metal cans or jugs, the capacity of which was 40 qt. each. During warm weather these metal containers were often covered with insulating jackets made of felt or blanketing in order to prevent heating of the supposedly cooled milk while standing on freight platforms, etc. These cans were shipped back and forth to the city dairy from the farmer who was sometimes at a distance of a hundred or more miles. The room required for these awkward containers and the handling required were excessive, but they were used for decades. In addition to these factors the city milk plants had to clean thousands of these cans daily and solder up holes in the can covers which the farmers regularly but with fallacious reasoning made to enable the more rapid escape of "animal heat" from the milk.

Within the last decade much of the milk shipped any considerable distance to the large cities is received at country collecting stations in cans. Here it is refrigerated in large receiving and cooling tanks. When the milk train goes to the city, it is composed of highly insulated cars containing other tanks which are glass- or enamel-lined, seamless, and of several thousand gallons' capacity. The cold milk from the receiving tank is pumped through a sterilized hose into the car tanks which are clean and practically sterile, as they have been previously washed, then rinsed with chlorine solutions, and sometimes heated with live steam. The milk is cooled to a temperature close to the freezing point. With such a large quantity of ice-cold milk no refrigeration is needed in the well-insulated car which holds two such tanks. A mechanical agitator is installed in the tanks to prevent gravity separation of cream when the car is not in movement. In runs of 300 miles the temperature rise even in summer is less than 3°F. from the time the milk leaves the country collecting station until it reaches the city pasteurizing plant. This method is far preferable to the old system. (See Fig. 36.)

Similar tank cars have been used for the transportation of milk for condenseries and cheese factories, for the handling of cream, and for ice-cream mix. They have also been used to transport refrigerated tomato pulp and juice from the producing areas to the canning plant. The increased use of such facilities seems assured in the future.

Refrigerator Cars with Ammonia Systems.—Refrigerator cars are in use which employ ammonia as the refrigerant in a compression system of refrigeration. The gas is compressed by means of power furnished by the axle when the car is in motion. When the car is not moving, an electric motor furnishes power for the compressor, although the use of auxiliary power is not necessary for short stops as brine tanks are installed at each end of the car to provide reserve refrigeration for such occasions. Expansion coils are in direct contact with, and surround, the brine which

is frozen when the power system is in operation. The condenser is air-cooled and is located on the roof of the car. Thermostats are used to regulate the temperature of the interior of the car. This type of refrigeration avoids the drip which accompanies the use of ice and enables cars to be maintained at any desired temperature, a factor which is sometimes very useful. It also eliminates the time delays necessitated for re-icing those cars having ice bunkers.

Refrigerator Cars with Solid Carbon Dioxide as a Refrigerant.—Solid carbon dioxide, or dry ice, may also be used as a refrigerant in place of ice and salt mixtures. Two well-insulated bunkers constructed of metal are located in the upper ends of the car. It is possible to carry sufficient carbon dioxide to refrigerate the cars for two weeks in one charge of 3,000 lb. The bunkers are gastight and allow the controlled introduction of the carbon dioxide as it is needed. Shipments have been made in such cars maintained at $-20°F.$ and may be made at any ordinary temperature of refrigeration equally well. Thermostatic control enables temperatures to be kept within a range of a few degrees. This method has the advantage of being adapted for the transportation of frozen foods which are usually maintained at very low storage temperatures; it will doubtless come into wider use as the increasing use of carbon dioxide lowers the cost of this material.

The development of these more modern methods of refrigeration in transportation has focused attention on the great necessity for the most efficient means of insulation for floors, walls, and roofs of cars. The same factors are of equal importance to the manufacturers of cars using ice which must meet the competition of the newer methods.

Silica-gel Refrigeration in Cars.—A comparatively new type of refrigeration system has been installed within the past five years in some refrigerator cars which use silica gel, a material prepared from the acid treatment of sodium silicate, which has a remarkable power of absorption of certain gases and water vapor. Sulphur dioxide gas is the refrigerant used in this system and is allowed to expand in a series of pipes which run lengthwise in the car. These pipes are a little below the ceiling of the car and have troughs underneath to collect any drip due to condensation on the pipes. The gas is condensed by an air-cooled condenser located on the roof of the car but protected from the rays of the sun. The absorber is in two sections, one at each end of the car, and consists of vertical tubes which contain the silica gel. These tubes are insulated in a fireproof compartment, and the heat used to expel the gas from the silica gel is furnished by gas burners supplied from tanks located under the floor. The two sets of absorbers are used in order to allow constant refrigeration, as one set absorbs the gas while the other is restoring the power of absorption to the silica gel. This system is so constructed that

the same car may be heated instead of refrigerated should temperatures outside necessitate such action. There is said to be a considerable saving of space afforded by this method. No icing delay is needed and constant temperatures can be maintained at any point.

Refrigerated Trucks.—Any of the above methods of refrigeration may be used in trucks and vans which are designed for the transportation of perishable or frozen foods. The use of crushed ice and salt is the oldest method and still the most common, but for certain types of food materials the adoption of other methods, similar to those mentioned in respect to freight cars, has demonstrated marked advantages. The use of solid carbon dioxide has proved particularly satisfactory for the reasons outlined above and also because it has a high refrigerating value per pound and therefore relatively small space is required for it in the truck. The absence of drip eliminates losses from corrosion and rotting of wood. The more recent developments in the use of carbon dioxide ice include separate tight compartments for the refrigerant with thermostat-controlled air circulation and finned radiators, although many trucks merely have bunkers for the solid product which is volatilized in the food compartment.

Another means of refrigerating trucks is by means of cartridges, or metal containers, containing frozen brine which are placed in small cabinets or insulated trucks. The food containers and their contents are frozen previous to being placed in the trucks. The length of time which they will maintain the desired temperature is usually not over 24 hours. Temperature ranges from −10 to 45°F. may be obtained in this manner.

This method is more commonly used for the transportation of ice cream and dairy products than for any other purpose. The compartments in which the foods are stored on the trucks are usually opened by doors on the top to avoid the greater losses of refrigeration when side opening doors are used.

TYPES OF MECHANICAL REFRIGERATION SYSTEMS

There are three standard systems of refrigeration by mechanical means: compression, absorption, and air. In the compression system, a compressor removes the gas, or vapor, from the evaporator, compresses it, and delivers it to the coils of the condenser. In the condenser, the vapor which is under pressure and therefore has an increased boiling point, is cooled by running water or by air. The cooled compressed vapor passes through an expansion, or reducing valve, into an evaporator. The compressed vapor, or gas, expands under reduced pressure and in so doing absorbs heat from the surroundings. The system consists then of repeated cycles of compression, condensation, expansion, and evaporation.

The absorption system differs from the compression system principally in the manner of increasing the pressure between the evaporator and

condenser. Instead of the compressor, there is a closed tank built to withstand pressure and which is fitted with coils. The tank holds the refrigerant which is usually ammonia, and water. The coils are alternately supplied with steam and water. Water at a temperature of 55°F. absorbs nearly 1,000 times its volume of ammonia, but when the temperature is raised only 25°F., ammonia is evolved freely from the aqua ammonia. Thus, in the absorption system, ammonia vapor is removed from the evaporator by reducing the temperature of the aqua ammonia in the closed pressure tank. Cold water is passed through the coils to bring about the cooling of the aqua ammonia. Since the absorption process precedes the heating of the aqua ammonia, the ammonia is present in the water at a concentration of only about 25 per cent. Ammonia is thus absorbed to the highest extent possible under the given conditions. At the point of maximum absorption, the cold water is shut off and steam at about 270°F. passed through the coils. Ammonia is driven off until its concentration in the water of the tank is again about 25 per cent, when the cold water is admitted to the coils once more. The ammonia driven off from the closed pressure tank is condensed in the condenser coils in a manner similar to that of the compression system. From the condenser, the ammonia flows through an expansion valve to the evaporator as in the compression system. The absorption system therefore substitutes the alternate use of heat and cold in a closed pressure tank containing aqua ammonia for a compressor. Heat brings about an action which corresponds to compression, and cold an action which corresponds to suction.

The air system of refrigeration consists of two essential parts: the compressor and the air engine, or motor. Air is compressed to a high pressure by the compressor and is then cooled by passing through coils over which cold water is run. The cooled compressed air is made to drive an air engine and in so doing it becomes expanded and very cold. The cold or refrigerated air is piped off for use in refrigerating rooms.

REFRIGERANTS

A refrigerant is a material which removes heat from the surroundings. Refrigerants may be classified in respect to (1) their ability to support combustion, and (2) explosiveness. Among the refrigerants which do not support combustion and which will not explode are sulphur dioxide, carbon dioxide, dichlorodifluormethane, methylene chloride, carbon tetrachloride, trieline, and nitrous oxide. A group of inflammable refrigerants which will support combustion and may explode under the proper conditions include ammonia, methyl chloride, ethyl chloride, butane, isobutane, carbon bisulphide, chloroform, dieline, ethane, ether, and propane.

In selecting a good refrigerant several properties must be considered. It is desirable to select a refrigerant with a fairly low boiling point. The pressure of gas or vapor in the evaporator should be a little above atmospheric pressure in order to prevent air and moisture from penetrating into the system. If pressures are high, it becomes necessary to employ unusual care in the construction of the system, which entails added expense. Corrosive action of the refrigerant upon the metals with which it comes in contact in the system is of great importance. Ammonia attacks brass or alloys of copper and brass so that these materials cannot be used where the refrigerant is ammonia. Some refrigerants are noncorrosive in the pure condition, but when mixed with water, oil, or grease, they become corrosive.

Since refrigerants are used over and over, it is necessary to select a substance which will not disintegrate during the repeated processes of compression, condensation, and evaporation.

A small volume of gas per pound of refrigerant is desirable, for the volume per pound in the cooling coils of the evaporator at the given pressure determines the size of the compressor cylinder. At the same time, a larger latent heat of evaporation is of decided value.

The initial cost of the refrigerant may have some bearing on the selection. Leaks in the system and the incorporation of impurities make it necessary to change the refrigerant after some time.

Ammonia, NH_3, finds an extended use in large refrigeration plants. Only anhydrous ammonia is used in the compression system. It is very soluble in water and its weight per volume is large. Anhydrous ammonia has only a slight or no effect upon petroleum lubricating oil. Water and ammonia react with copper and brass and to some extent on steel. Ammonia does not burn at ordinary temperatures. It is irritating to animal membranes and, for this reason, its use as a refrigerant in dwellings is not desirable. Sulphur candles are used to detect leaks.

Sulphur dioxide has no effect upon metals unless water vapor is present, when there is corrosion of copper, zinc, and iron. There is a tendency for the absorption of oils. Since light-colored oils are not absorbed so readily, these are usually employed. Nearly three times as much displacement in the cylinder of the compressor is required as is the case with ammonia. Leaks may be easily detected with aqua ammonia, for a dense white cloud is formed when sulphur dioxide comes into contact with aqua ammonia. Owing to the fact that leakage of sulphur dioxide is easily recognizable and the gas very pungent, causing one to seek fresh air at once, sulphur dioxide is used in household refrigerating machines.

Methyl chloride, CH_3Cl, is used as a household refrigerant. Although inflammable, it does not burn readily. It has no effect upon iron, steel, copper, or copper alloys. About all oils are dissolved by methyl chloride,

except white mineral oils. These mineral oils and glycerine are used as lubricants in systems employing methyl chloride. Glycerine has the disadvantage of freezing at times in the evaporating or cooling coils and thus preventing further circulation of the refrigerant. The cylinder displacement for methyl chloride is smaller than for sulphur dioxide but larger than for ammonia. More than 10 per cent of this gas (by volume) acts as an anesthetic, while higher concentrations sometimes produce death by suffocation.

Ethyl chloride, C_2H_5Cl, is similar to methyl chloride in its effect upon the body. There is no corrosive effect upon the metals used in refrigeration. Glycerine is used for lubrication. The displacement is larger than for sulphur dioxide or ammonia. It is possible to operate the compressor at lower pressures than for other refrigerants. Ethyl chloride may be used in household refrigeration.

Carbon dioxide, CO_2, has been used a great deal on shipboard and in hospitals as a refrigerant. Carbon dioxide is noncorrosive to the metals ordinarily used in refrigerating systems. It has no effect on lubricants except that due to low temperatures produced; a low-temperature oil or glycerine must be used for lubrication. This gas has about one-fifth the cylinder displacement of ammonia for a similar quantity of refrigeration. The compressor, condenser and piping must be especially constructed on account of the high discharge pressures. It is difficult to detect carbon dioxide leaks, but the gas is not dangerous or irritating to the animal membranes.

Dichlorodifluormethane, CCl_2F_2, or "F-12," is said to approach the ideal refrigerant. It is nontoxic, noninflammable, nonexplosive, noncorrosive. It mixes with mineral oils, with no separation or formation of an oil blanket in the evaporator. The piston displacement is greater than for ammonia.

Methylene chloride, CH_2Cl_2, is not affected by aluminum, copper, lead, tin, and soft steel. The piston displacement is much greater than for ammonia.

Certain terms common to the engineering aspects of refrigeration industry are defined below.

British thermal unit (B.t.u.), a very widely used standard or unit, is the amount of heat required to increase the temperature of 1 lb. of water 1°F. between 32 and 33°F. One B.t.u. is equivalent to 778 ft.-lb.

Specific heat is the quantity of heat expressed in B.t.u. required to raise or lower 1 lb. of the substance 1°F.

The commercial unit or standard commercial ton of refrigeration is the quantity of heat required to melt 2,000 lb. of pure ice into water at the freezing point, thus extracting 228,000 B.t.u. per 24-hour day, 12,000 per hour, 200 per minute, or 3.3 B.t.u. per second.

The latent heat of liquefaction, the heat required to produce melting, is 144 B.t.u. per pound of ice.

METHODS OF FREEZING FOODS

There are many methods of freezing foods in use at the present time, although the same fundamental idea is involved in all of them, namely, to maintain a temperature sufficiently low that the activity of microorganisms will be reduced to a minimum and the autolytic action of enzymes present in the foods will be largely inhibited. The methods of refrigeration best suited for various types of food depend largely on factors which differ with the biological nature of the food, the length of time which the food must be preserved, the circumstances under which it must be obtained, and the type of refrigeration available.

A marked increase in the types and quantity of food frozen has occurred in the past decade. Meats, fish, fruit products, and broken-out eggs have constituted a large part of the increment. The use of freezing processes extends the storage life of these products considerably over that possible by refrigeration at the ordinary temperatures of cold storage. It has also enabled a wider use of these products in various forms in regions where they were previously unobtainable in many seasons, and sometimes were never available.

The various methods of freezing now used include the following, each of which may have numerous modifications:

A. Open-air freezing, freezing in a cold air blast.

B. Freezing by direct contact of the product and the refrigerant or by means of a refrigerated spray.

C. By indirect cooling contact of the product and refrigerant through the use of cans, sheaths, pans, refrigerated metal belts, plates.

D. By direct or indirect contact with compressed gases such as carbon dioxide in solid form.

Combinations of certain of the above methods are sometimes used to accomplish the same objective. A number of these methods have attained usage in the fishery industries.

A. Open-air Freezing.—Open-air freezing, *i.e.*, natural freezing, is unquestionably the oldest from the standpoint of use and at the same time the simplest method. This method has been used in the regions having sufficiently cold seasons for probably as long a time as man has existed there, although primitive man had no knowledge of why freezing was essential to the preservation of his food supplies. The fact that it served the purpose was sufficient evidence for the method to be used whenever possible. All that is necessary is the exposure of the food out of doors. When, for example, one fishes through the ice on very cold days, it is only necessary to let the fish that are caught lie on the ice until fishing is

over. After a short time the fish are frozen solid and can be kept in that condition until used. In commercial practice many foods are merely put in rooms at subfreezing temperatures until frozen.

Many fruits are now frozen in combination with sugar in barrels or tins. These products when packed in barrels may require several days before the contents are entirely frozen because of the poor rate of heat exchange, but the large concentrations of sugar prevent spoilage. Pre-cooling the materials before packing in barrels reduces this time considerably. For berries this method is particularly applicable as a large part of these fruits are used in preserves, jams, jellies, pie fillings, etc., which ultimately require the addition of sugar. Some of these frozen-pack foods are later repacked in small retail containers of paper, base materials for domestic use, and may be again frozen, but the greater portion is packed in bulk for food manufacturers.

Freezing in a cold air blast, sometimes called sharp-freezing, is applied particularly to fish. In the sharp-freezing of fish it is customary to place the fish which are to be frozen in covered pans or on galvanized-iron sheets which are placed on brine pipes. Refrigerated brine at the desired low temperature is circulated through the pipes. The air circulation is often forced by means of fans. Large fish such as salmon, sturgeon, or halibut are frozen individually on the sheets. It is advantageous to put the fish in pans during the freezing process to avoid as much dehydration as possible and likewise to facilitate heat transfer. Sometimes the pans are covered with metal covers. The moisture losses may also be lessened by a preliminary water or oil dip. A water dip after freezing which forms an ice glaze on the product after removal from the pans also lowers dehydration during subsequent storage.

Fish are delivered to the freezer either by direct conveyor system or by trucks. The temperature of the freezer before the fish are taken in is generally below 0°F., although it may rise when first loaded if large quantities of material have been received. The temperature starts to drop again after a time, depending on the load of the freezer, and will eventually approach the temperature of the brine in the pipes. The length of time the fish are left in the freezer is somewhat dependent on the demands for the room, as the shortest possible time is used when there are many fish to be frozen. In general circumstances small fish are left in such freezers for 24 hours, larger fish for 2 days and the largest for a period of 3 or more days. At the end of this period the frozen products are transferred to storage rooms.

Large amounts of frost are deposited from time to time on the brine pipes, especially in freezers, owing to the crystallization of moisture, and tend to reduce the efficiency of the refrigeration system. This frost should be removed at intervals. It can be readily done by hand scrapers

or sometimes is accomplished by allowing a warm brine solution to flow through the pipes. The latter method is obviously a wasteful and expensive procedure. After the pipes are defrosted, it is particularly necessary to guard against undue dehydration of the products being frozen because the temperature of the bare pipes will tend to precipitate the moisture in the air, lower the humidity, and hasten loss of a part of the water from the food.

Sharp-freezing, as briefly outlined, offers a simple method of freezing fish in large quantities. It is not widely used for other foods.

A description of operations in one plant which packs fish fillets in 25-lb. boxes and then freezes them, is outlined below.

Fish are mixed with crushed ice on one end of a conveyor at the wharf. The conveyor carries the fish to cypress holding bins located on the top floor of the building. Other conveyors are arranged to transport the fish from the bins to a washing tank, from which they are lifted to a weighing machine by still another conveyor. The object of weighing is to realize the maximum amount of efficiency from the workers. The men are paid according to the quantity of fillets which they secure from a given amount of fish. Standards for yields are set up and an increase or decrease in respect to these standards is compensated by a bonus or a penalty. The men work at each holder or station. The weighed fish, as they approach on an endless belt, are shunted into the station which needs them by the weigher who pulls a lever causing a projection to be thrown across the path of the oncoming load. The men cut out the fillets and place them in pans with a metal tag which identifies the operators. An endless belt carries away the scrap fish, while another one conveys the fillets to the weigher. These fillets are wrapped individually in parchment paper, packed tightly in 25-lb. boxes without covers, and conveyed to a freezing room. There the boxes are inverted so the open top of the box and the upper layer of fish lie in a flat pan. The pan is placed on racks of brine pipes at subzero temperatures and frozen in a few hours. Later the boxes are removed from the racks, the tops nailed on, and the packages removed to storage rooms maintained at low temperatures.

B. Freezing by Direct Contact of Product and Refrigerant.—In Norway one of the earlier methods of freezing fish utilized a stream of cold brine pouring over the packed fish. The brine was made from salt and crushed ice. In a country where ice is plentiful and salt is low in price this method may be satisfactory but such conditions are not common in the United States. One of the disadvantages of this method is that the distribution of the brine may not be uniform and thus an even freezing would be uncertain.

The spray method of direct-contact freezing is illustrated by the system used for fish and devised by Taylor. The fish are suspended from

moving bars, washed before entering a spray tunnel in which refrigerated brine is sprayed down from nozzles over the fish, after which they are again washed and glazed. The brine drops from the fish, drips off upon the cooling coils below, where it is lowered to the proper temperature and recirculated, thus being capable of use many times. This method utilizes mechanical devices for every purpose except hanging the fish on the moving bars. The time necessary for freezing is relatively short.

Ottesen devised a method whereby he froze fish in perforated metal baskets by immersing them in brine in a concrete tank. The brine was cooled by direct expansion coils in the tank and kept in motion by means of paddles. The advantage of his process lay in a principle of physical chemistry which he applied. When ice crystals are in equilibrium with the brine, the penetration of salt into the fish is least. At a certain concentration of the brine, there would be a definite temperature when this equilibrium was established. Naturally the temperature was highest at a low concentration, slightly below 32°F. With a salt concentration of 21.4 per cent, it was found that a temperature of −6.16°F. could be reached, which is the lowest temperature that can be attained by this method.

The brine fog or "Z" process, devised by Zarotschenzeff, involves the utilization of a refrigerated fog of atomized brine sprayed into a freezing chamber where it may come in direct contact with the food to be frozen. This method has been used for fish in Europe, both on land and on fishing boats. It has also been used for freezing ducks, poultry, meat, and fruit. By enclosing the foods in containers it may be used as an indirect method. This system, which may be continuous, allows the brine or sodium chloride solution to be atomized into a fine mist or fog. This mist is discharged in the freezing cabinet, thereby coming in contact with the food, or its container if the indirect method is used. When the particles of brine gravitate to the bottom of the cabinet the solution is collected, refrigerated, and recirculated. The freezing compartment may have adjacent to it another compartment maintained at a temperature close to freezing temperatures to cool the food to this level previous to the actual freezing process which takes place in a relatively short time. If the brine has come in direct contact with the food, the product is sprayed with fresh water subsequent to the freezing process to remove any residual brine. At the same time the product may also be glazed with a thin coating of ice if such a coating is necessary. A mechanical conveyor system may be used to move the food through the various compartments, making the process an automatic one. Instead of brine it is possible to use a sugar solution or sirup in the same manner. This has obvious advantages in freezing fruits, etc.

C. Freezing by Indirect Contact.—Freezing by indirect contact is quite widely used at the present time and recent developments indicate that methods utilizing this principle will be much more extensively used in the near future.

Petersen[1] developed a method of freezing fish by placing them in narrow rectangular cans which are subsequently immersed in brine at a temperature of from −25 to −30°F. This method may be used either for fish which are gutted or in the round, and with or without heads. Previous to freezing the fish are given a preliminary treatment by washing in a solution, said to be germicidal or antiseptic in nature. After this treatment, the fish are packed in flat scoops or pans which are so designed that they slip easily into the freezing cans. The cans are joined together to facilitate handling. A typical can produces cakes of frozen fish 2 by 18 by 28 in., although cans of any size may be used, according to the particular demand. After the scoops containing the fish are slipped into the cans, they are withdrawn and the fish allowed to settle into place. Not more than 45 minutes is required to freeze the 2-in. blocks of fish. A low temperature is essential because the heat exchange through the metal can and then through the fish would be quite slow at moderate freezing temperatures. Following the freezing, the cans are lifted out of the brine by a mechanical hoist, dipped in lukewarm water or brine, and the cakes of frozen fish slide out easily. Individual fish are not accessible for removal by this method and there is likely to be some distortion in the shape of the fish. Cakes of fish are easy to handle, however, and when properly glazed by covering the exterior by a thin film of ice are better protected against rust and drying.

In the Cooke system which utilizes this principle, an endless belt of aluminum plates with 5-in. fins on the under side to increase the rate of heat transfer is used to convey fillets of fish through a solution of refrigerated brine. The freezing room has an average temperature of −10°F., while the brine is kept at −20°F. As the plates containing the fillets enter the freezing room, the fins dip into the brine. Thirty to forty minutes is required to freeze the fillets at a temperature of about −20°F., so the speed of the belt is adjusted so that the fillets will be entirely frozen before emerging from the brine in a space outside of the freezing room. The plates are then warmed slightly by passing through brine at 60°F. but only long enough to loosen the fillets from the plates so they can be removed. This system was designed to freeze fish in thin portions without wrapping, using moderately low temperatures and a good heat-conducting surface, in order to accomplish the freezing with economy.

One system devised by Kolbe employs shallow round galvanized-steel pans. These pans hold about 3 lb. of fish. Freezing is accomplished by

[1] Petersen, P. W., *Food Ind.* **2**, 193, 1930.

allowing the pans containing the fish to float along through a slightly inclined labyrinth of raceways which are insulated to cut down refrigeration losses. The raceways are 24 in. in diameter and are long enough so that by the time the pans have traversed the entire length of the raceway, the contents of the pans are thoroughly frozen. Since the pans strike against the sides of the raceway at intervals, their progress is necessarily slower than the brine, a factor which tends to assist the freezing process somewhat because the brine washes up against the side of the pans and increases the area of contact with heat-conducting surface. Centrifugal pumps add brine to the raceways at the rate of several hundred gallons per minute, depending on the quantity needed, and cause a gentle flow through the raceways. The brine at $-15°F.$ freezes the fish in a short time. One modification of this method uses covers on the pans and sprays brine on the tops of the pans through perforated pipes which follow the course of the raceways. This spraying is reported to cut down the time of freezing to a considerable extent. At the end of the circuit the pans are removed from the raceways, turned upside down, and tapped to remove the frozen fish. (The fish are later wrapped in such form as they have taken in freezing.)

Another method of indirect freezing is the Birdseye process which enables foods to be packed previous to freezing. Like the several systems mentioned previously, it is called a quick-freezing process in contrast to others which require somewhat longer periods of time for the actual freezing of the materials.

An earlier indirect process was devised by Kolbe, using diving-bell pans which have covers and are submerged in calcium chloride brine maintained at subzero temperatures. The foods to be frozen, generally fish fillets, are placed within the pans.

Quick-freezing.—Quick-freezing is one of the important recent developments in food refrigeration and differs from the older methods of freezing in several respects. It requires less time for the actual freezing; the product when defrosted is subject to less leakage and in many cases resembles the original more closely; some quick-freezing methods enable better handling of the product in its frozen form.

By the use of lower temperatures of the refrigerants and the more rapid transfer of heat by conduction rather than by the earlier methods utilizing convection, it has been possible to cool foods through the so-called "zone of maximum crystal formation" in a comparatively short time. This zone of maximum crystal formation lies between approximately 25 and 31°F., according to Plank.[1] By reducing the time foods are in this critical zone where large ice crystals form from the water content of the foods, there are smaller ice crystals developed instead. This is an

[1] Plank, R., *Z. ges. Kälte-Ind.*, **32**, 141, 1925.

advantage because most frozen foods are primarily composed of either plant or vegetable cellular materials, the cell walls of which may be ruptured when very large crystals are formed, as usually occurs in the sharp-freezing process. Other changes in the protein compounds which comprise an important part of the cellular tissue occur during the freezing period but are less serious in quick-freezing as the colloidal materials are coagulated and not completely precipitated as in sharp-freezing.

Quick-freezing, since it produces small-sized crystals, does not rupture the cell walls of many foods. It is, however, not applicable to all kinds of foods, depending on their physical and chemical structure. The cell walls of spinach are ruptured by quick-freezing, but in this case no harm is done, for the time required for cooking is materially shortened. The size of the crystal makes no difference in the case of the strawberry, for in freezing the delicate membranes are altered so that the juice escapes very quickly upon thawing. Raspberries withstand quick-freezing very well in respect to the preservation of the qualities associated with the fresh berries.

The loss of juices upon thawing is not entirely prevented by quick-freezing. A product thawed very soon after quick-freezing does not lose much juice, but the loss of juice increases with the length of time in storage. From this it would seem that rupturing of cell walls was not the only factor that caused a loss of liquid from the frozen goods.

Taylor[1] mentions the fact that one can take animal tissues—meat or fish—and grind them up in a mortar with sand thus disintegrating the cell walls, yet there is not much loss of juices even upon the application of considerable pressure. Of course, in the case of fruits and vegetables there is a different problem, for the cell walls are inelastic and easily ruptured, and also there would be considerable loss of juices following cell rupture. Admitting these facts, it appears probable that some reaction goes on in frozen foods which causes the permeability of the cell membrane to become increased and the cell contents to become more liquid in nature. Taylor believes this action to be possibly in the nature of an autolysis, for some time is required and the cell walls are seemingly not ruptured. Enzymes work much slower at low temperatures.

The exact nature of the changes taking place in the frozen products is unknown. The animal cell, containing as it does protein in colloidal form, water, and salts in solution, besides many other compounds in various states, is a complex affair. In the process of freezing, pure water freezes first; *i.e.*, there is a tendency for the impurities to be frozen out. An increase in the concentration of salt would favor changes within the cell. Salt in dilute solution increases the solubility of certain proteins (peptization), while in concentrated solution it precipitates some proteins

[1] Taylor, H. F., *Food Ind.*, **3**, 205–206, 1931.

from solution, producing a dehydration. Very likely some proteins may be precipitated at their isoelectric point owing to a changed condition of pH upon the death of the animal. Then, as already referred to, there is the question of autolysis, or self-digestion of the cell and its contents. All these things would tend to separate the liquid from the solid, or diminish the colloidal matter in the cell by increased solubility.

Quality in the finished product depends not only on the method of freezing, but upon the pretreatment and the type and quality of the raw materials used, the packaging, storage of the frozen product, length of storage, and care in handling until it reaches the table.

Each of the methods discussed under B and C may in a sense be considered quick-freezing processes in that in each it is possible to complete the freezing in much less time than in cold air, provided the refrigerants are at sufficiently low temperature. Certain of them display marked advantages over the others, however.

It must be emphasized that all frozen foods must be stored at very low temperatures, 0°F. or below, for optimum results. If kept at much higher temperatures, marked changes occur in storage longer than a few weeks.

Quick-freezing by the Birdseye Process.—Clarence Birdseye, as a guest of honor at a banquet tendered him by distinguished citizens of Boston, July 7, 1931, is quoted as having made the statement that "77 per cent of the world's food supply is highly perishable." This means that there is a tremendous amount of waste taking place, which in part, at least, is unnecessary. As has already been indicated, quick-freezing presents an ideal way for preserving perishable food. Quality and flavor are well retained in most articles. Long periods of time do not alter the keeping qualities, provided the goods are stored appropriately. Freezing within the package, a process devised by Birdseye, insures the initial appearance, saves packages, storage space, and a large expense in shipping. Not all foods, however, on account of their physical and chemical structures, can be frozen with equal success.

One of the chief articles of food which was earliest and most advantageously quick-frozen by this process was fish. An establishment employing the Birdseye process operates as follows: The fish are unloaded from the vessels onto conveyors, which carry them through a tank containing sea water chlorinated at the rate of 4 to 5 parts per million. This preliminary treatment is intended to destroy the bacteria upon the surface of the fish. Emerging from this bath, the fish are dumped into clean wooden boxes with a capacity of about 600 lb. each. These boxes when filled are iced and hauled by tractors a short distance to the holding room, which, at a temperature of 36°F., is considered sufficiently high to prevent dehydration from the surfaces of the fish, but too low to permit the ice to melt in quantities large enough to bathe them. The

fish stay in the holding room only a short time—just enough for the machines to be ready for them.

The first operation in the plant for such fish as are not skinned is the removal of the scales. This was formerly done by a machine in which a hook drags the fish through the machine by the head so that bronze strips revolve against the scales and remove them without injuring the skin, which has good food value and serves to retain the flavor of the fish. Chlorinated sea water is sprayed down upon the fish during the scaling. In the more recent practice manual scaling is done using an electrical device.

After scaling, the fish once more pass through a tank of chlorinated sea water. They are then conveyed to a series of hoppers, into each one of which a definite quantity is dumped. In front of each hopper two men stand at a cutting table of monel metal. The fillets are cut out, put in monel pans, and weighed. Scraps are dropped onto a moving belt and conveyed away.

Some fillets are prepared from skinned fish. Skinning may be done by a machine with a vibrating knife, which does its work as efficiently as is possible by hand manipulations. The fillets for the 1-lb. package are cut in 5-in. lengths by circular knives.

Before packaging, the fillets are passed through a salt brine (35° Salometer), the time of immersion being about 17 seconds. This treatment does not preserve, but imparts an improved flavor to the finished product.

Fillets are packed in packages of three sizes: 1-lb. (3 by 5 by 2 in.), 5-lb. (7¼ by 10 by 2 in.); and 10-lb. (10 by 15 by 2 in.). The fillets for the 10-lb. package are weighed out and placed in circular pans of monel metal which pass along an endless belt past the packing tables where girls take the pans as needed, wrap each fillet in moisture and vaporproof cellophane. These wrapped fillets are then packed in waxed cartons. Fillets for the 1-lb. package are put up in a similar manner, except that the carton is first lined with waxed vegetable parchment. The cartons are finally machine-wrapped in waxed glassine and sealed by means of a hot iron. Practically an airtight package is formed. The packaged fillets are now frozen by the Birdseye quick-freezing process, which is described later.

After freezing, the frozen goods are stored in a room where a temperature of -15°F. is maintained until shipped. Special shipping boxes of corrugated cardboard with a lining of four or more layers of strawboard are used to transport the frozen products. The boxes are sealed so as to be airtight and are then such efficient insulators that they may be shipped across the country without extraordinary refrigeration.

Halibut weighing 200 lb. have gone through the same method as 1-lb. packages of fillets, and any product of intermediate size can be easily accommodated, by changing the time factor. This process was first used

commercially for fish, but has since been extended to a great variety of foods of both plant and animal origin. It has been instrumental in opening the vista of a tremendous industry which has the opportunity of making the most delicate and perishable foods available at a reasonable price to people who may be thousands of miles from the region where the foods were produced. The limitations of such an industry are wide, provided the pioneers in it realize that a great deal of scientific and economic research is necessary to determine what foods and what varieties can be frozen to best advantage, and profitably handled after the freezing process is completed. It may be said that this new industry has been inaugurated with, probably, more research and scientific preliminary preparation than any other food industry of equal magnitude the world has known.

Within the past five years the products which have been frozen by the Birdseye process have been extended from the original fish fillets, to shellfish of all kinds, meats of all kinds, berries of practically every kind, spinach and other greens, vegetables, fruits, sausages, poultry, fruit juices, cream, ice cream, and in fact almost every conceivable type of food. Not all kinds of plant foods are frozen with equal success because of changes in color, texture, or taste in some types. Careful choice of varieties and pretreatment methods may be necessary in some cases. Those foods which are being produced commercially and used to the greatest extent are fish products, meat products and poultry, shellfish, fruits, berries, spinach, and peas.

The original Birdseye belt method consisted of a double unit made up of four endless belts of monel or Allegheny metal, two belts 44 in. wide and the other two 36 in. wide. This is all enclosed in an insulated chamber. Two belts, one of each width, constitute one-half of this assembly and is really a freezing unit in itself. The wider belt constitutes the top of the freezing chamber and overhangs the narrow belt by 4 in. on each side. The actual freezing surface of the belts is 50 ft. in length, but the belts themselves are each over 100 ft. in length because it is only the lower surface of the upper belt and the upper surface of the lower belt that make up the freezing surface at any one moment. While these huge metal belts themselves are really going in opposite directions, the freezing surface presented by the lower part of the upper belt and the upper surface of the lower belt are traveling in the same direction and are regulated to run at the same speed. The speed of the belts may be regulated as need arises, and their movement stopped at will if it is desirable to leave some types of food exposed to the refrigeration for a longer time than is required for a single passage.

The distance between the two belts which form the effective freezing surface may be regulated, as the size of the packages which are frozen may differ. As previously noted, the top or wider belt has a 4-in. over-

hang on each side. This 4-in. strip of belt on the side is bent down and over the edge of the narrow bottom belt.

The actual refrigeration is obtained by the use of brine, calcium chloride, which is sprayed down on the top belt and up against the bottom of the lower belt of the freezing chamber. The brine then drops by gravity into a series of insulated tanks below. The reason for the overhang on the top belt is because bending over the projecting sides allows the brine to drip down into the collecting tank below without coming in contact with the material to be frozen. The collected brine is recooled to its original temperature, −40 to −50°F., by means of a mechanical carbon dioxide refrigeration apparatus. Rollers located above the upper belt,

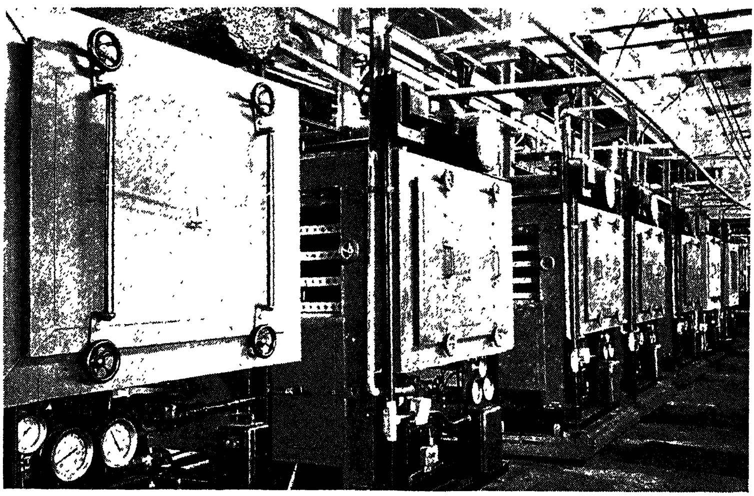

FIG. 60.—Birdseye multiplate freezers. (*Courtesy of Food Industries.*)

and the weight of the belt itself exert a pressure upon the packages, as they traverse the length of the machine, sufficient to maintain the original shape of the package in which the material to be frozen is packed.

The freezing of food materials in the final package in which it is to be sold has several advantages, foremost of which is the conservation of space, because if the material is packed in the container before freezing, it is at that time more plastic and can be fitted into the container with much less air voids between the units, whether the food be fish, meats, berries, or vegetables. The saving of space also means savings in transportation costs and storage. It also results in a saving in the amount of wrapping material necessary to cover the final product, and this is an important factor in view of the cost of various types of transparent wrapping material which are commonly used. By having the package more completely filled, better conduction and heat transfer are also possible.

Much experimental progress has been made since this type of freezing equipment was developed, and the belt freezer has pointed the way toward the Birdseye multiplate freezer which displays numerous advantages over its predecessor.

At the same time the need for research concerning the freezing properties of many foods has been recognized and followed intensively. Varietal characteristics have determined what materials are best suited for such treatment. Methods of pretreatment, storage, and handling, even to the optimum cooking conditions suitable to have the product in its finest condition when it arrives at the table, are now known for many products.

The markets for these types of products have widened, the demand has increased with the dispersion of knowledge that such foods are available at all seasons, and refrigeration facilities in stores for handling such foods are becoming increasingly common, especially in urban districts.

The more recently developed quick-freezing apparatus which has largely superseded the belt freezer earlier described is the Birdseye multiplate freezer which consists of a series of superimposed hollow plates which are internally refrigerated. They are so arranged that they may be separated from each other by means of lazy tongs and may be closed by a hydraulic piston. The food material to be frozen, usually in packages, is placed between the plates and the plates then closed, thereby enabling contact of each package with two freezing surfaces. These units may be stationary and in sizes capable of freezing 1,500 lb. or more per hour, or sufficiently small to have the entire unit, which of course is highly insulated, mounted on a motor truck and mobile. Direct-expansion ammonia refrigeration in a self-contained system is a part of the apparatus and is connected with the various plates by means of flexible hose made of rubber.

The mobile unit, which may be operated wherever electric power is available, is particularly efficient as it enables the use of the freezing unit in various regions during different parts of the year. As most of the fruits and vegetables of suitable varieties for freezing may be raised in widely separated geographical areas and at different times of the year, it is possible to use such a unit, for instance, for the freezing of strawberries in Florida or some other Southern state early in the summer, to move the truck to Delaware for the lima bean or pea season, later to set up the freezer in New York for apples, and during winter months to use the same unit for fish or meats if desired. Such operations permit a wide diversity of usage and eliminate the need of a permanent stationary freezer in one place which would have use for only a limited period, unless products were shipped to that point, which would mean that no longer would strictly fresh foods be frozen.

The use of such mobile freezers offers a logical tie-up between freezing and canning operations because canneries in various regions have the cleaning, grading, and other equipment used in the preliminary operations needed for foods of many types which may be both frozen and canned. As the canneries are forced to have permanent locations and equipment by nature of their operations, such a combination of activities might have mutual advantages.

The freezing of foods will doubtless increase as time goes on, but there seems no reason to believe that all foods will be frozen to the exclusion of canning. Although freezing preserves the flavors and favorable characteristics of a large number of foods, it is not true with all. Foods which are frozen, even though preserved under optimum conditions of refrigeration, may on long storage undergo changes of chemical, structural and enzymic nature which are not desirable. Refrigeration over considerable periods of time is an expensive process. Relatively few stores and practically no homes are as yet equipped with storage space for refrigerators suitable for maintaining temperatures sufficiently low for the proper handling of frozen foods for prolonged periods of time. The common electric refrigerators now in general use, although satisfactory for ordinary foods, should be used only for the temporary storage of frozen foods, unless specially designed to maintain the necessary lower temperatures needed for frozen products.

Containers for Frozen Foods.—The type of container used for frozen foods varies greatly. From the barrels used in the Northwest and the Delaware peninsula for berries and fruits, the tubs and firkins for butter and lard, the large cans for broken-out eggs, the flat boxes of wood or tin for fish, one comes down to the various domestic units used for a multitude of frozen foods. Cartons of 1-, 3-, and 5-lb. capacity made of cardboard and lined with various transparent wrapping material have attained wide usage. Treated paper cups and tubs have been used for some frozen berries, juices, and other liquid materials. Tin sanitary cans of various types have also been utilized for frozen foods.

The changes which occur in frozen foods are not unlike those which may be expected in fresh-food materials from the standpoint of spoilage. When they are thawed out or unfrozen they will spoil as readily as foods which never had been frozen, and possibly with greater acceleration. The consumers must be educated in this respect, as it is apparent that many do not appreciate this fact and believe that frozen foods, like canned foods, will keep indefinitely as long as the package or container is not opened.

So long as frozen foods are still in a frozen condition they are subject to dehydration unless covered with a film of ice or oil, or packed in tins, moistureproof wrappings or containers. They are also subject to oxida-

tive processes, particularly those foods containing fats and oils. This type of change may be lessened by preventing contact with oxygen, which requires airtight packages, a difficult problem unless metal containers are used. It has been found that even with tin containers some fruits are best packed by vacuum-closure methods to keep discoloration at a minimum. The use of salt in some instances and the use of sugar in others have caused some improvements in texture, color, and flavor, but the optimum method of treatment and preliminary treatment must be determined empirically for each product and each variety.

The quality of the food frozen is also an important consideration. Only the highest quality food should be frozen. Freezing does not improve foods, except possibly meats which may become somewhat more tender. Poor products will remain poor products regardless of what freezing process may be used. Freezing combined with storage at low temperatures doubtless cuts down the incidence of bacteria of some types, but there are always some of the more resistant types which survive for any period of time likely to be feasible for commercial utilization. Yeasts are more likely to be susceptible to freezing and storage than molds.

While frozen and in a solid condition, foods are not subject to serious changes due to microorganisms if the storage temperature is 0°F. or below, but their action is apparent in a short time when exposed to higher temperatures and precautions must be taken to avoid such conditions previous to utilization.

The evidence at hand indicates that quick-freezing tends to conserve the vitamin content of foods so treated in comparison with unrefrigerated foods of the same origin.

It has also been found that quick-freezing by lowering the temperature of raw pork to 0°F. for 24 hours will eliminate any danger due to the presence of Trichinella larvae. Under the present meat-inspection regulations pork so infected must be held at 41°F. for 20 days or heated to 137°F. in order to be safe.

This method of food preservation has resulted not in just another method but has laid the foundation for a new industry. The growth of this industry has been relatively rapid within the past decade and gives evidence of much greater progress in the years to come.[1]

Freezing Orange Juice.—The juice from sound oranges is sterile, but it contains enzymes which cause deterioration. Oxidation is a form of deterioration which is combated by the use of deaeration and vacuumized cans.

[1] For an extended authoritative text on this subject the reader is referred to the very recent text, The Freezing Preservation of Fruits, Fruit Juices and Vegetables, by D. K. Tressler and C. F. Evers. The Avi Publishing Co., New York, 1936.

There are several methods[1] of freezing the juice. One company freezes the juice to a slush in vertical ice-cream freezers which are minus the beaters. This prefreezing requires about 6 minutes and serves to prevent the separation of the fibrous material and to inhibit the action of microorganisms. The juice is then forced out of the freezers by nitrogen gas into two types of containers: one, waxed-paper cups, and the other gallon tin cans. Both containers are sealed under vacuum. Following this packaging, the juice is hardened in an air blast at $-10°F.$, a process requiring from 6 to 12 hours.

In the preliminary steps of another process, the oranges are washed in sodium hypochlorite solution to sterilize the surface, the juice is expressed and deaerated. After sealing the juice in paper bottles, they are attached to a conveyor which takes them through brine at a temperature of $-10°F.$ The total time of exposure to freezing is 40 minutes, but the juice is frozen within 32 minutes—quick-freezing. The cans settle 2½ in. into the brine during the first 2½ ft. of the journey; then slowly they dip till 4½ in. of the can is immersed (cans are 5⅞ in. tall). At this depth the cans remain until frozen. Immediately upon freezing, the cans are packed in corrugated paper containers for shipping and stored at around 10°F.

In another method, the orange juice is strained into 1-gal. tin cans, which are sealed under vacuum. The cans are frozen in brine at 0 to $-2°F.$, being left in for a period of 6 hours. At the completion of this period, the cans are packed in shipping cartons and stored at temperatures ranging from 0 to $-10°F.$ (See Chapter XIX for other methods.)

Frozen Peaches.—In Georgia, a state renowned for its peaches, the best peaches do not withstand storage even for short periods. The same peaches cannot successfully be canned.[2] Quick-freezing offered a ready solution to the problem, yielding a peach not deficient in flavor, taste, or appearance.

The peaches are first sorted and the sound fruit passed on to a peeling machine. This machine contains a vat of caustic soda solution through which the peaches are slowly passed. A jet of cold water removes any skin left from the lye treatment, and also washes away traces of the caustic soda solution. The seeds are extracted from the peaches at work tables and then machines automatically slice the peaches for packing cartons. After being packed in the cartons, a sirup made up of 29 lb. of sugar to 300 gal. of hot water, which has been cooled to 40°F., is added. Speed is essential up to the point of adding the sirup and sealing to prevent oxidation and discoloration of the fruit.

[1] Burton, L. V., Florida Produces Frozen Orange Juice, *Food Ind.*, **3**, 208–211, 1931.

[2] Baker, C. T., Freezing Georgia Peaches, *Food Ind.*, **2**, 496–498, 1930.

The sealed cartons are packed in wire baskets, the baskets placed in one end of a tunnel on a gravity conveyor, and air at a temperature ranging from −30 to −35°F. is blown through the tunnel at high velocity. The tunnel is located in a refrigerating room, is about 30 ft. long, and cork-insulated.

After freezing, the cartons are packed in cardboard containers and stored at 8 to 10°F., prior to shipment.

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CHAPTER XVI

DEHYDRATION

The drying of foods is a process of ancient origin which man copied from nature, and has used and somewhat improved with the passing of the centuries. Some of our most important food materials, such as grains, seeds of legumes, and nuts reach maturity or ripeness and then undergo drying or dehydrating changes while still attached to the plants on which they have been borne. This natural dehydration, resulting in highly concentrated food materials of enduring keeping quality is especially favored by climatic conditions in which there is little or no rainfall at the time of the harvest season. Wet weather at this time, or improper storage in moist conditions after the harvest, may result in serious spoilage and deterioration which would not otherwise occur.

Certain types of sweet fruits, such as raisin grapes, figs, and dates also undergo loss of water after ripening, and are preserved by the concentration of sugar thus brought about. Fruits of this character can only be successfully cultivated in those regions which have long dry seasons with hot sunny days. The nut crops, because of the heavy and hard shells in which the nutritive portion of the seed is contained, are less subject to the conditions just mentioned.

Early man may have depended solely on nature as a means of drying foods sufficiently to preserve them, but doubtless with the development of shelter for himself, man gathered fruits, roots, and other plant products under the same shelter, exposing them to the sun to dry only when conditions were favorable. The use of heat for the same purpose when sunshine would not suffice has been recognized and practiced for many centuries. Drying by sun and by fire was used by the Indians before the advent of white men in this country. Our early New England colonists and their predecessors from France who established fishing colonies farther North, used sun-drying for their fish in order to preserve their products, sometimes supplementing this type of drying by salting, which by the affinity of the salt for moisture also takes water from the tissues of the product. The fish were usually split and dressed previous to drying, thus producing larger surface areas and at the same time exposing cellular surfaces which were more water-permeable than the fish skins, thereby facilitating the drying. Within the past generation it has been a common sight in New England and in other apple-growing regions to see the

quarters of peeled and cored apples strung on threads like beads and hung on frames near farm kitchens to dry for later use in the pies which were made during winter and spring months. Even salt has been obtained for many centuries by allowing the salt water from the sea to be evaporated from shallow pools or ponds made by constructing dikes until the concentrations of salt were sufficiently high to cause crystallization. Even now such salt works on a large scale may be seen in California.

REASONS FOR FOOD DRYING AS A MEANS OF PRESERVATION

The reason that foods which have been subjected to drying, whether by natural or artificial means, are thus in a state of preservation is primarily because of their lower moisture content. As is well known, the microorganisms which are the usual causative agents of spoilage—the yeasts, molds, and bacteria—and the enzymes elaborated by them or inherent in the foods, are unable to carry on their usual activities if the water content is sufficiently low. Such activities, which eventually result in more or less advanced decomposition, are therefore suspended or inhibited unless water is returned to the materials, or until it has been reabsorbed to a sufficient extent. Furthermore, the microbes themselves lose water by drying and are rendered inert. As the microorganisms are not all killed, however, it is possible for them to remain dormant for long periods of time. With the subsequent establishment of higher moisture conditions, spoilage may result in a short time. Even with fairly low moisture content enzymatic changes of undesirable or commercially deleterious nature are likely to occur, though the rate of such changes is greatly retarded. In most dried foods exposed to the circulating air, fluctuations in moisture take place as the humidity varies. Weather conditions in many areas cannot be relied on to be favorable for drying fruits or other foods if fine products are sought, and outdoor drying or sun drying must therefore be supplemented by other means. Fruit products such as raisins, apricots, and prunes are sun-dried to a considerable extent, but such operations in this country are confined largely to California where climatic conditions, except in unusual circumstances, are favorable. Even in the inland valleys of California some fruit growers have found it advantageous to hasten the drying by artificial means.

One of the largest crops in this country, the hay crop, has always been harvested with the old adage "make hay while the sun shines" in mind until rather recently, when it has been found economically desirable to dry hay and similar forage crops, such as alfalfa, by mechanical means in order to conserve the nutritional value for animal feeding. Under such circumstances the adage no longer holds.

Drying is one of the simplest, cheapest, and most effective means of preserving foods. Sun drying is the most simple method of drying. The term *evaporated* foods is used quite commonly to distinguish foods which have been dried, but by some other means than sun drying. It is quite frequently used in respect to apples which are dried in evaporators, or warmed kilns, the air movement being by means of natural draft. *Dehydration* is a term used generally to denote drying which has been accomplished by artificial means; it is usually reserved for artificial drying methods employing a forced draft of conditioned air by means of fans. All of the drying methods, however, rely on the removal of water by evaporation in the original sense of this term.

Many food products are now dehydrated, including raisins, prunes, apricots, peaches, apples, cherries, cranberries, potatoes, carrots, seaweed or kelp, spinach, malt, milk, cream, skim milk, eggs, fruit juices, beef, fish, and numerous others. With the refinement of processes and equipment, certain of these dehydrated products, particularly milk products, have tremendously increased in use in the past two decades.

Although drying of foods has been practiced for many centuries, no record of any aid by artificial means existed until the end of the eighteenth century when Graefer treated vegetables with hot water for a short time and then exposed his products to drying conditions. The same method was later applied by Dize to meat. Somewhat later (1795) Eisen was credited with the idea of heating the air in a room by means of a stove and building racks around for drying. This led to the construction of numerous small dry houses in central Europe. In 1820 hops were artificially dried by Vallence who referred to the process as desiccation. The real originators of dehydration are said to be Masson and Chollet, French investigators. The former cut vegetables in thin slices and dried them at low temperature, and he was later joined by Chollet who helped in developing the mechanics of a system whereby air flow at a temperature of 105°F. was used and the dried materials were later compressed by hydraulic pressure. Later reports by others stated that flavors were unimpaired by such methods and that compression increased the density, and facilitated preservation, storage, and transportation of such substances. Military records show that in 1863 dried compressed vegetables were used on a limited scale as a part of the food ration in the Union Army in the Civil War.

Drying of potatoes on a semicommercial scale was started in Australia about 50 years ago, and in the Western United States, soon after, the product was used in considerable quantity in the rush to the Klondike fields in 1896. In Germany there were 3 small drying plants in 1898, which were increased to 199 in 1909 and to 841 in 1916, the latter increase being largely due to the increased use of such products in Germany during

the World War. Some 1900 plants were in operation in 1917, assisted by facilities for drying in 2,000 breweries. In 1919 there were about 25 drying establishments in the United States.

The drying of milk is another process which Marco Polo has been credited with observing in his Asiatic travels some seven centuries ago. Nicholas Appert, the French originator of the process of heating of foods in sealed containers (see chapter on Canning) to preserve them, has also been cited as having dried milk over a hundred years ago. The practical commercial processes of milk drying are of more recent origin, however, and go back only about 50 years in this country. The first commercial product to attain wide usage was malted milk, although in the past two decades other dried-milk products have dwarfed the importance of malted milk. The quantity of dried skim milk produced is much greater at present than the production of dried whole milk, dried cream, dried buttermilk, and malted milk combined.

RELATIVE ADVANTAGES OF DEHYDRATION

There are a number of fundamental reasons which favor the utilization of the process of dehydration of foods. These may be considered especially in relation to vegetables. It enables foods to be saved for future use which might otherwise spoil. It presents a means of extending the period of use of essentially fresh foods over a time longer than the growing period of each, and widens the group of consumers of a particular product which might otherwise be confined to the regions of production.

From an economic standpoint, dehydration may serve somewhat to level the peaks of consumption and production, as it furnishes the possibility of making the dried products at a time when the cost of the raw material is cheapest and the quality is best, and disposing of them when the production has decreased or ceased and the demand therefore increased.

Dehydration has a decided advantage from the standpoint of transportation in that the shipping weight of the final dehydrated product is only a small fraction of that of the original food, depending somewhat on the type of food concerned. The bulk or volume of the dehydrated food is also minimized, which is of particular importance in ocean shipments and in national emergencies.

The majority of dehydrated foods, if properly manufactured and properly prepared for the table, are very good substitutes for fresh foods and sometimes can only be detected from the fresh foods with difficulty. The nutritional values are conserved to a marked degree.

Dehydrated foods do not require special sterilization or the maintenance of sterility in preparation, which is a decided advantage to the manufacturer. One should not be led to infer, however, that any less

care of the raw materials or operations is necessary. These are essential for good products.

There is a distinct economy in use, since there is no waste and only the amount of dehydrated food necessary for use at one time need be prepared. This is often not the case with canned foods unless they happen to be available in small-size cans. The cost of containers is likely to be less, owing to concentration of the food material and the ability to use special types of inexpensive packages.

From the standpoint of health, dehydrated foods, like those properly prepared by canning or freezing, are satisfactory.

On the other hand, there are some practical objections to dehydrated products which it would be unfair not to mention.

Dehydrated vegetable products generally require both soaking, for the restoration of the water lost in drying, and cooking before use. The soaking or rehydration time is not the same for all kinds of products as some absorb water rapidly and others slowly. Lack of attention to this detail may result in improper preparation leading to criticism of a blameless product. One of the most difficult tasks of food manufacturers is the attempt to teach purchasers to read labels and follow directions, and if the rehydration is not carefully done according to directions, the results are likely to be unsatisfactory.

Dehydrated foods do not always reach the consumer in good condition, even though they may leave the producer in the best of condition. This may be partly due to damage to packages or sometimes to insect infestation as a result of indiscretion in the choice of packages and containers which are not insectproof or moistureproof. In the latter instance, it is possible for the contents of such packages to absorb enough moisture from the air to permit bacterial or mold action and thus cause the product to undergo incipient deterioration or even to spoil if not checked. Some dehydrated foods are quite hygroscopic, while others are less prone to take up atmospheric moisture. Any spoilage, discoloration, or change of flavor which does occur in dried foods is not likely to be observed except after purchase by the consumer. This is injurious to the whole industry, whereas in canned products the common "swell" or spoiled can seldom gets beyond the retailer and is usually segregated before he receives it.

From the above discussion it is apparent that certain advantages are presented by dehydrated products from the standpoint of cost, weight, and space, factors which are particularly essential in expeditions, in the tropical countries, in the outposts of the world, and for military operations. Desiccated products were used in the Civil War, especially to minimize the incidence of scurvy. During the Boer War similar products were used. The World War stimulated production of millions of pounds of such products for troops in Europe, where fresh foods were a rarity.

Those particularly capable of use in military operations at that time were dehydrated potatoes, turnips, cabbage, onions, carrots, tomatoes, beets, and spinach.[1] More recently the Byrd Antarctic expeditions have shown the great value of dehydrated foods.

Today in addition to those foods already mentioned, no surprise is expressed when one finds dehydrated milk of several kinds, eggs, spinach, orange juice, cherries, garlic, and other equally unlike products—a considerable difference in range compared to the few products of a hundred years ago, which included sun-dried apples, samp, or dried boiled corn, which were examples of those materials prepared in each home for personal consumption during the winter months. Notwithstanding the potentialities in dehydration of vegetables and fruits, the industry is not an expanding one except in a few lines.

The two most important dehydrated fruits in the United States during the past decade were raisins and prunes, and these same fruits were the most important dried-fruit exports. In 1927, prune exports amounted to over 225 million pounds and raisins over 175 millions. The consumption of dried fruits in the United States has apparently increased in recent years to approximately 5 lb. per capita per year, according to Montgomery.

DEHYDRATION METHODS AND EQUIPMENT

The drying of fruits and nuts in the United States was largely carried out by sun drying previous to the World War, with the exception of dried or evaporated apples. This was due to the fact that such products are manufactured almost exclusively in California where the fruit-producing areas are generally warm and sunny during the harvest season and rain is unusual during those periods. The apple season comes somewhat later in the year and for that reason evaporators have proved more certain means of properly drying this fruit. Unseasonable weather in 1918 caused severe losses to prune and raisin growers, and since that time the development of more efficient dehydrators has caused many fruit growers to install such equipment. Fruit dried in dehydrators also enjoys the advantage of being much cleaner than that exposed in dry-yards to the dust which is prevalent in many such areas. According to Christie,[2] there are over 1,000 modern dehydrators with controlled heat and humidity in operation for the drying of fruits and nuts. The controlled dehydration of walnuts has also been found to be advantageous. The majority of dehydrators for this purpose are heated by either gas or oil,

[1] For a more detailed discussion see Prescott and Sweet, *Ann. Am. Acad. Pol. Soc. Sci.*, vol. 82, May, 1919.

[2] CHRISTIE, A. W., Dehydration Costs for Fruits and Nuts, *Food Ind.*, **3**, 478, 1931.

both being available at relatively low rates in California, but electricity has been used as a heating medium in some 60 dehydrators.

There are numerous types of equipment utilized for the drying of various foods, ranging from the inexpensive and relatively simple kitchen-stove drying cabinets used by the housewives on many farms in order to preserve excess fruits and vegetables, to mechanically designed, efficiently constructed dehydrators capable of handling large tonnages of raw materials.

Evaporators.—Some of the commercial dryers operate with an air circulation dependent only on the natural draft resulting from the rising of heated air. These types, which are designated as "kilns" or "evaporators" have attained usage in the drying of such diversified products as apples, potato starch, and hops. Apples so dried are called "evaporated apples." Kilns may be several stories high with gratings of wood or metal in place of the usual floors, and on which the material to be dried is placed in a shallow layer. In the basement below this series of gratings is a furnace or other source of heat such as a bank of steam pipes, which heats the air. The heated air rises, passes through the successive layers of material to be dried on the gratings above, and takes up moisture therefrom. The sliced undried material is usually spread first on the top-floor grating, and at intervals the materials on the gratings are dropped to the next floor below until it reaches the first floor where the drying is completed and the product removed. The heated air is at its highest temperature and most capable of removing water when it comes in contact with material on the lowest floor which by nature of the operations contains the least water. It is obvious that as the air rises to the upper floors containing materials with increasing water content, the residual water-absorbing capacity of the heated air is further utilized. Many such kilns use the heated air but once and have a relatively low thermal efficiency. The control of temperature must be watched carefully in order to eliminate wide variation in the moisture content and quality of the final product.

Forced-draft driers, in contrast to natural-draft driers and kilns, are generally constructed with a forced-air-recirculation system which enables the utilization of some of the heat still remaining in air which has passed through the dehydrating equipment only once. Recirculation of air is an economy from the standpoint of fuel consumption. Some forced-draft driers are constructed in compartment units which have a circulation of heated air maintained by power fans and a definite inlet and outlet flue from each compartment.[1]

[1] *U. S. Dept. Agr. Bull.* 1335, 1925.

Tunnel Dehydrators.—Tunnel driers are most commonly used in the fruit-dehydrating industry on the West coast, particularly in California and Oregon.

These tunnels are usually between 30 and 40 ft. long, 6 ft. wide, and 6 ft. high, constructed of tile, concrete, or wood, and so arranged that both the air current and the material being dried are moving in a horizontal plane. These driers are constructed so that trucks carrying stacks of trays of the fruit may be moved through the tunnel on narrow-gauge tracks. Such units are equipped with high-velocity fans and heating units of large capacity generally using oil for fuel. They afford much more accurate control than natural-draft systems. The air may be heated directly by the flame or indirectly by the use of flues which surround the heating unit. The latter method prevents products of combustion from coming directly in contact with the food. Steam-pipe systems may also be used but are less economical.

The trucks with carefully spaced trays of raw material are started along the tracks at one end of the tunnel and eventually are taken out at the other, thereby making a continuous process. The direction of the trucks may be with or against the air current, which is generally maintained at a velocity of several hundred linear feet per minute, although the countercurrent method is more common. By this method the final product just before removal from the tunnel is subjected to the highest temperatures and the lowest relative humidity, while the fresh material just entering the tunnel comes in contact only with air which is lower in temperature and higher in humidity because of its previous contact with the food being dried in the tunnel. Even at this end of the tunnel the air is not cold, however, and it is conveyed back through ducts to the heating system, being mixed with various proportions of outside air, in order to lower the humidity, and used again, thereby conserving heat.

FACTORS RELATING TO PROPER CONTROL OF DEHYDRATION

There are four factors which have an intimate relation with the optimum dehydration of food materials; temperature, relative humidity of the air, air velocity, and time. The proper control of each is essential. Temperatures higher than 165°F. are not generally recommended for fruits and vegetables and may be considerably less for some products. If combinations of temperature and humidity are such that moisture evaporation from the surface of the material being dried is greater than the rate of diffusion of moisture from the interior of the plant cells to the surface, an undesirable condition results. This condition is known as casehardening, a term borrowed from the metallurgical industries, indicating the formation of a hard, sometimes horny, relatively impermea-

ble surface skin which prevents or greatly retards further moisture reduction.

It is essential to dry foods in as short a time as possible but conditions of humidity and temperature must be such that casehardening does not result, also that the physical condition of the product and its nutritive and organoleptic qualities are not injured or altered any more than may be avoided. The proper combination of recirculated air and outside air is intimately concerned in this respect, as are the air flow and the type and amount of material being dehydrated. Many of the engineering

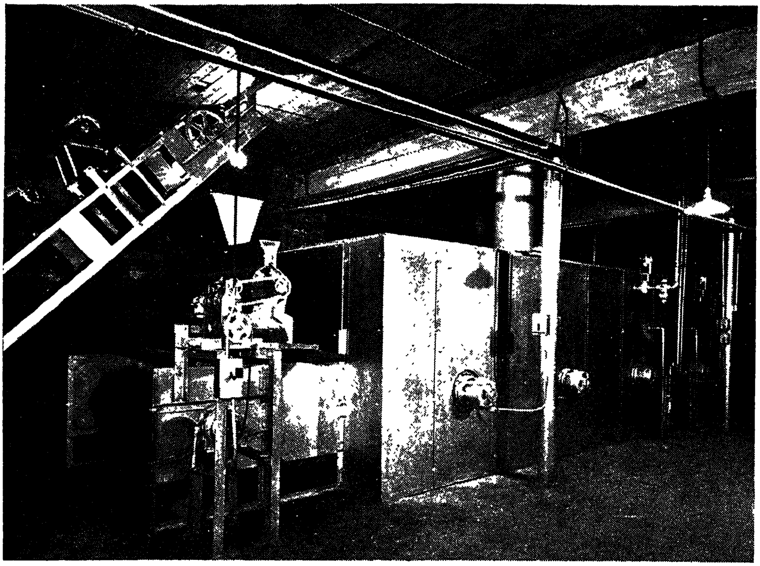

FIG. 61.—Dehydrator. (*Courtesy of Proctor and Schwartz, Inc.*)

aspects of dehydration, as well as other phases, are discussed in U. S. Department of Agriculture Bulletin No. 1335. The senior author of this bulletin, the late Paul F. Nichols of the University of California, spent more than 15 years in this field of research, and published numerous papers concerning the dehydration of foods.[1]

In addition to tunnel driers there are commercial vegetable driers which utilize endless metal-screen conveyor belts whereby materials may be automatically conveyed through heated chambers maintained at relatively low temperature with circulating fans to maintain the desired air movement. The heat is sometimes supplied by steam pipes within the chamber and the time of drying regulated by adjusting the speed of the conveyor.

[1] CRUESS, W. V., Commercial Fruit and Vegetable Products, 1924.

Other methods of drying foods by means of heat are used for special products. Dehydrated eggs are produced by both drum driers and modified tunnel dehydrators using trays for the broken-out eggs, *i.e.*, after removal from the shells. Powdered milk is produced by drum drying and spray drying, often preceded by a partial concentration of the milk under vacuum. Some driers using centrifugal force have been devised for the removal of water in other dehydrated products.

Both drum driers and spray driers may be so designed and constructed as to operate in a partial vacuum, thereby lowering the temperature necessary for removal of water and lessening chemical and physical changes in the resulting products.

PROCESSES PRELIMINARY TO FRUIT AND VEGETABLE DEHYDRATION

There are numerous preliminary preparations which are necessary before some foods are dehydrated, dependent on the raw material to be used. Careful selection and sorting of the fruit or vegetables is essential because dehydration, like other food preservations, does not make good foods out of poor ones. Selection for size and maturity is particularly important from the standpoint of equal drying of the finished product. Many raw foods are washed previous to drying; some are peeled either by hand or by dipping in a lye bath. Some are also pitted, halved, quartered, sliced, or shredded, thereby eliminating stones, cores, seeds, and other waste materials and at the same time increasing the surface area of cellular tissue. This tends to lower the drying time.

The dispatch with which these preliminary operations are conducted is closely related to the final quality of the products. Enzymic changes may occur in comparatively short periods of time and certain fruits and vegetables are susceptible to color changes which are definitely undesirable. Microorganisms are accelerated in growth and activity at elevated temperatures such as normally occur in the drying areas of the Pacific coast. Such changes should be kept at a minimum.

Preliminary chemical treatments have been found necessary for some fruits and vegetables. Blanching, or a brief treatment by means of hot water, saline or lye solutions, steam, and other agents, are helpful in checking some enzymic changes. The use of steam rather than water dipping minimizes losses of mineral salts.

Some fruits, such as apricots and peaches which are not ordinarily blanched, are treated by exposure to the fumes of burning sulphur or "sulphuring" as it is called, after cutting and pitting. This process lessens the discoloration and is believed to produce changes in the permeability of the plant cells which are favorable to the subsequent drying operations. It also kills any insects present in the material. Sulphuring is generally carried out after the halved, pitted fruit has been placed on

TABLE 108.—DETAILS OF DEHYDRATION OF FRUITS AND VEGETABLES*

Product	Removal of inedible portions	Yield of fresh prepared from fresh unprepared, per cent	Subdivision to form for drying	Approximate tray load per square foot, lb.	Pretreatment		Maximum drying temperatures, °F.	Average drying time, hours	Dried product				
					Type	Time, minutes			Preferred moisture content, per cent	Characteristics	Keeping qualities**	Yield, per cent	
												From fresh prepared	From fresh unprepared
Fruits:													
Apples........	Peel, core, trim.	65–75	Cube or slice.	1.5	Sulphur.	15–30	140–160	6–10	10–15	Dry, springy.	Good to fair.	16–19	10–15
Apricots.......	Wash, halve, stone.	90–94	Dried in halves.	2.0	Sulphur.	15–25	135–155	10–20	15–20	Dry, leathery.	Good to fair.	17–20	15–19
Bananas......	Stem, peel.	52–57	Dried whole or sliced.	1.0	Sulphur.	15–30	140–160	10–20	15–20	Slightly moist to sticky, limber.	Good to fair.	28–31	13–18
Cherries (unpitted).	Wash, stem.	97–99	Dried whole.	1.0	None or steam.	0– 2	135–160	8–12	15–20	Slightly moist to sticky, limber.	Excellent.	25–30	24–30
Cherries (sweet) (pitted).	Wash, stem.	77–83	Dried whole.	1.0	None or steam.	0– 2	135–160	8–12	15–20	Slightly moist to sticky, limber.	Excellent.	24–28	18–24
Cranberries ...	Wash, stem.	100	Chop.	.8	None or steam.	0– 2	135–150	4– 8	5–10	Dry, tough to brittle.	Excellent to good.	10–14	10–14
Figs..........	Wash.†	100	Dried whole.	3.0	Boiling lye dip.‡	1/12–1/2	135–160	10–20	15–20	Skin dry, glossy; flesh slightly moist.	Good.	24–27	24–27
Grapes........	Stem and seed after drying.	80–90	Subdivide clusters.	3.5	Boiling lye dip.‡	1/12–1/2	150–180	20–30	15–20	Skin dry, glossy; flesh slightly moist.	Excellent to good.	26–30	21–27
Loganberries ..	Wash.†	100	Dried whole.	1.2	None.	.....	140–150	10–15	10–15	Dry but should not crumble.	Excellent to good.	15–18	15–18
Peaches.......	Halve, pit, peel.	85–90	Dried in halves.	2.5	Sulphur.	15–30	145–155	15–24	15–20	Dry, leathery.	Good to fair.	17–21	14–19
Pears.........	Peel, halve, core.	75–80	Dried in halves.	2.5	Sulphur.	15–30	140–150	15–25	10–15	Dry, leathery.	Good to fair.	17–20	12–17
Prunes........	Grade for size.†	100	Dried whole.	3.0	Boiling lye dip ‡	1/6–3/4	145–160	20–30	15–20	Skin dry; flesh slightly moist.	Excellent to good.	33–38	33–38
Raspberries (black).	Wash.†	100	Dried whole.	1.0	None.	.....	140–150	10–15	10–15	Dry but should not crumble.	Good.	16–20	16–20
Rhubarb......	Trim stalks, wash.	55–60	Slice.	1.0	Steam.	2– 4	140–150	10–15	5–10	Dry, tough.	Good.	6– 9	2– 7

Vegetables:												
Beans (green)	Trim, wash.	87–92	¾-inch lengths.	0.8	Steam.	15–20	140–155	8–12	5–10	Dry, tough to brittle, greenish-black.	Excellent to good.	10–13	8–12
Cabbage	Trim.	80–85	Slice or shred.	1.0	Steam.	2– 6	140–150	8–12	5– 7	Dry; ribs tough; leaves crisp.	Good to fair.	8–12	6–10
Carrots	Wash, peel, trim.	77–82	Cube, slice, or shred.	1.5	Steam.	4– 8	150–160	8–12	5–10	Dry, tough to brittle.	Excellent to good.	11–14	8–12
Celery	Trim, wash.	77–82	Slice or shred.	1.0	Steam.	1– 2	135–145	§3– 6 ‖8–10	5–10	Dry, stalks tough; leaves crisp.	Excellent to good.	6– 9	4– 8
Corn	Husk, cut from cob after processing.	35–40	Kernels dried whole.	1.7	Steam.	15–20	150–165	5–10	5–10	Dry, brittle.	Excellent to good.	25–28	8–12
Onions	Trim.	88–93	Slice or shred.	1.2	Steam.	½–1½	135–140	5–10	5– 7	Dry, crisp.	Good to fair.	12–15	10–14
Parsnips	Wash, peel, trim.	77–82	Cube, slice, or shred.	1.2	Steam.	2– 5	150–160	8–12	5–10	Dry, tough to brittle.	Good to fair.	18–22	14–18
Peas (sugar)	Shell, clean, grade.	55–60	Dried whole.	1.0	Boiling water.	1– 2	140–150	8–12	5–10	Dry, hard, wrinkled.	Excellent to good.	18–22	9–14
Potatoes	Wash, peel, trim.	78–82	Cube, slice, or shred.	1.2	Steam.	5– 7	145–155	8–12	5–10	Dry, brittle.	Excellent to good.	22–25	17–21
Pumpkin	Wash, stem, cut open, seed.	70–75	Cube, slice, or shred.	1.5	Steam.	3– 6	140–155	12–16	5–10	Dry, tough.	Excellent to good.	7– 9	4– 8
Squash (Boston Marrow)	Wash, stem, cut open, seed.	70–75	Cube, slice, or shred.	1.5	Steam.	3– 6	140–155	14–18	5–10	Dry, tough.	Excellent to good.	11–14	7–11
Spinach	Trim off roots, wash.	45–55	Leaves dried whole.	0.5	Steam.	2– 5	140–150	6–10	5– 7	Dry, crisp.	Good to fair.	7–11	3– 6
Sweet potatoes	Wash, peel, trim.	75–80	Slice.	1.5	Steam.	6– 8	150–160	5–10	5–10	Dry, brittle.	Excellent to good.	32–35	24–28
Tomatoes	Wash, trim,† peel.	70–85	Slice.	1.2	None or steam.	0– 3	140–150	10–14	5– 8	Dry, brittle.	Good to fair.	5– 8	3– 7
Turnips	Wash, peel, trim.	75–80	Cube, slice, or shred.	1.2	Steam.	2– 5	145–155	8–12	5– 7	Dry, tough to brittle.	Good to fair.	10–12	7–10

* Taken from Bulletin 1335, U. S. Department of Agriculture.

** Based on quality after storage for one year.

† Operation is optional.

‡ Use 1 to 3 per cent lye solution. After lye dipping, rinse fruit by momentary dip in fresh cold water.

§ Leaves.

‖ Stalks.

trays racked on trucks. The trucks are pushed into small sulphur houses where the fruit is subjected to the vapors of sulphur dioxide, SO_2, from burning sulphur in small pits just beneath the floor of the closed compartment. If the fruit is to be sun-dried more severe sulphur dioxide treatment is given than for that mechanically dehydrated. Compressed sulphur dioxide gas from cylinders may be used for the same purpose, although it is not so common. Apples and pears which are to be dried are sulphured for the same reasons. Previous to freezing for pie stock, apples are sometimes dipped in sulphurous acid, H_2SO_3, made by passing sulphur dioxide gas from cylinders into a tank of water.

In general the treatment of cut fruits, apricots and peaches, requires less than an hour's exposure in the sulphur house to be satisfactorily sulphured, and this exposure results in a sulphur dioxide content of about 1,500 parts per million. The limits of sulphur dioxide which may be allowed in dried fruits vary greatly in different countries, as well as in different states (0 to 2,500 parts per million).

It has been found that sulphuring tends to conserve the vitamin C in dehydrated apricots and peaches.[1,2]

Table 108 outlines the general procedures advocated for the handling and treatment of dehydrated fruits and vegetables by Nichols, Powers, and Gross. The choice of optimum procedures depends on many factors including the variety, stage of maturity of the raw material, color, presence of oxidase enzyme systems,[3] efficiency of the dehydrator,[4] and other equally important factors. Very careful preliminary experimental work is necessary to establish proper operative conditions for any particular product, taking into consideration not only the raw material but the use and market for which the finished product is intended.

PROCEDURES AFTER DEHYDRATION

Storage.—After the drying or dehydration operations are completed, it is customary to store the products in relatively large quantities in bulk for a period of several weeks so that an equalization of moisture may take place. This is carried out on a commercial scale by the use of large bins which may hold a number of tons of dried product. During the storage a relative equilibrium is established as the drier-finished material picks up moisture at the expense of that less thoroughly dried. After this period the products may be boxed, packaged, or shipped.

Insects.—Dried and dehydrated foods are subject to numerous insect infestations during storage and should be protected against insects as

[1] Morgan, Field, and Nichols, *J. Agr. Research*, **42**, 35, 1931.
[2] Morgan and Field, *J. Biol. Chem.*, **82**, 579, 1929.
[3] Cruess and Fong, *Fruit Prod. J.*, **6** (3), 13, 1926.
[4] Cruess and Christie, *California Agr. Exp. Sta. Bull.* 337, 1921.

far as possible. Tight screening and well-lighted storage may be helpful but are sometimes impossible to maintain in practice. Exclusion of insect invasions is exceedingly difficult and fumigation is frequently utilized to lower the incidence of insects such as the Indian-meal moth (*Plodia interpunctella* Huebner), the saw-toothed grain beetle (*Silvanus surinamensis* W.), and the dried-fruit beetle (*Carpophilus hemipterus* W.) which are particularly damaging, the first being the most serious pest.[1] The same agents which are effective for grain fumigation may be used for dried fruits.[2] Ethylene oxide and carbon dioxide mixtures have proved particularly useful in this respect.

Packaging.—The packaging of these materials is also one of great significance, as invasion by insects and the access of moisture may spoil the products in a very short time. Not only are insectproof and moistureproof containers desirable, but with certain dehydrated products, exclusion of air is essential for storage. Powdered milk is a good example of the latter, and small retail packages of this commodity are packed with a vacuum process in tin containers. For the dried fruits the more common packages are moisture-resistant rather than moistureproof as the expense factor is involved.

Control of Dehydrated Products.—During the World War dehydrated foods assumed great importance in meeting the needs of our troops overseas and some thousands of tons of dehydrated Irish potatoes, turnips, carrots, onions, and other products were produced. Standards were needed for the purchase, quality and control of materials of this nature in order to have healthful, nutritious, palatable products. The foundation for the control of dehydrated foods may be gained by application of the same standards which were advocated during the World War period by Prescott.[3] The fundamentals of these standards outlined at that time and equally applicable today, are as follows:

1. *Raw Material.*—All fruits and vegetables used for dehydration shall be of good quality, free from disease, sun-scald, frosting, or other injury whereby they are rendered unsuitable in the fresh state for table use.

2. *Preliminary Treatment.*—All fruits and vegetables so used shall be thoroughly washed and given such other treatment, as peeling, trimming, hot and cold dipping, as may be necessary to secure the best quality of product, and these processes shall be performed with the same care as that used in the preparation of vegetables for the table or for canning.

[1] Hamlin, Reed, and Phillips, U. S. Dept. Agr. *Tech. Bull.* 242, 1931.

[2] See discussion of grain fumigants in chapter on Wheat.

[3] Prescott, S. C., Report read before Section on Food and Drugs, American Public Health Association, Oct. 28, 1919. What should be the basis of the control of dehydrated products?

If pretreatment by blanching or scalding is necessary to secure high-quality products, this treatment shall be conducted promptly and in a clean and sanitary manner. All utensils used for this purpose should be of suitable construction to insure sanitary handling.

3. *Process of Drying.*—No detailed process of drying can be specified, but the process should be so arranged and handled that the products will not deteriorate while in the drier, either from spoilage as a result of action of yeast, molds, or other microorganisms, or from physiological changes taking place in the material as a result of enzymes occurring naturally in the food itself. The process of drying should be so controlled that the food will not be seriously affected in color or have the flavor destroyed by scorching or for other reasons. The foods should lose only water during the process of dehydration and should not be so changed in physical structure that they will not return to approximately their natural form and appearance on being soaked in water. On proper soaking they should, within three hours at the ordinary temperature of the room, be restored to approximately their full size, and natural appearance.

4. *Protection against Spoilage.*—After dehydration, fruits and vegetables which have been dried for human food should be packed at once in suitable tight receptacles or stored in bins which have been specially prepared and which have adequate protection against vermin, insects, and molds and other microbic enemies. Such storage receptacles or containers should prevent access of moisture in sufficient amount to render the food material capable of fermentation or decomposition.

5. *Insects.*—The greatest enemies of the dehydrated products are certain forms of weevils and other insects which may gain access to them, lay their eggs in the material, and render them undesirable for food because of the development of worms and larvae. All dehydrated products should be specially examined for such insects and their webs or cocoons, feces, and eggs.

6. *Sanitation of Factory.*—The preparation of all dehydrated vegetables for army purposes should be conducted under cleanly and sanitary conditions and should be subject at all times to inspection by properly authorized officials. The methods of handling the finished product in the factory should be such as to preclude infection from boots, floors, and implements or any other external source. Care should be taken to impress upon the manufacturer that he is dealing with a food material and that it is essential for the welfare of the consuming public that such food materials should be placed before the consumer in a wholesome and uninfected condition.

The food value of such materials, if the dehydration has been properly accomplished, should compare favorably with its original level, as water is the only material removed. The vitamin C content may be somewhat reduced, however, although as has already been mentioned, sulphuring certain fruits tends to lessen this reduction. The great advantages of dehydration in enabling the utilization of food materials subject to waste in periods of surplus commend this method of food preservation to wider usage than it has attained at present.

PRODUCTION OF DRIED FRUITS AND VEGETABLES

There has been a considerable increase in the production of dried fruits in the United States during the past 30 years, as is apparent from Table 109. While our imports have remained relatively constant, there has been an increase of several hundred per cent in our exports and some apparent increase in per capita consumption. In the period from 1923–1927 about 60 per cent of our dried apples and 50 per cent of our dried apricots were exported. California produces all of our dried apricots, peaches, and pears and approximately 40 per cent of all the dried apples of the United States.

The dried-vegetable industry is one of relatively small magnitude at the present time, although it could be increased if a demand for such products became apparent.

The production methods used for certain of these products are cited below.

Table 109.—Dried Fruits in the United States

Year	Production, lb.	Imports, lb.	Exports, lb.	Apparent per capita consumption,* lb.
1899	84,737,900	75,719,733	65,580,938	1.27
1909	485,335,800	78,424,623	141,488,618	4.66
1919	615,408,528	78,699,119	291,534,110	3.83
1927	1,012,795,660	83,914,155	489,579,172	5.22

Dried Fruits and Vegetables, 1931†

Product	Source	Pounds	Value
Apricots...	California	74,138,344	$ 7,348,007
Figs.......	California	48,165,581	2,057,458
Peaches....	California	50,303,979	3,539,982
Prunes....	United States	447,195,917	19,941,193
Prunes....	California	400,885,303	17,870,499
Raisins....	California	391,921,237	20,538,957
Other fruit.	California	14,531,889	1,189,281
Other fruit.	Oregon	208,706	54,727
Other fruit.	United States	28,328,811	3,719,236
Vegetables.			251,989

* Montgomery, E. G., and Kardell, C. H., *U. S. Dept. Comm. Domestic Comm. Series* 38.

† *Biennial Census of Manufactures. U. S. Dept. Commerce, Bureau of Census,* 1931.

RAISINS

The production of raisin varieties of grapes, and the subsequent drying of the grapes to produce raisins, is an industry of considerable importance,

not only to California, which is the exclusive producing region, but to the entire country. In 1932 over a million tons of raisin varieties of grapes were grown, which constituted about 65 per cent of the entire California grape crop and over 50 per cent of the entire grape crop of the nation. In the same year over 100 million pounds of raisins were exported from the United States, having a value of over 5 million dollars, while only about 1 million pounds of raisins were imported. Greece and Spain are also exporters of raisins.

There are but few varieties of raisin grapes. The more important are the Thompson Seedless (Sultanina), the Muscat, the Sultana, and the Black Corinth, or currant, which is of minor importance. The Muscats, when naturally sun-dried, are known in international trade as Malagas.

Raisins may be dried in the sun or by the use of artificial dehydration.[1] Muscat and most of the other raisin grapes are grown in regions where ideal weather conditions for sun drying generally exist. The exceptions, however, when ideal climatic conditions do not prevail, may be the cause of severe losses. Under such conditions the use of dehydration equipment becomes of paramount importance. The variety which has been found most fitted for artificial dehydration is the Thompson Seedless, which when properly handled, is a competitor of the Smyrna raisin which is held in high esteem in the United Kingdom. Dehydration may also be used late in the season for drying table grapes when prices are such that further shipments are unprofitable, and the drying weather is uncertain.

Sun Drying.—Only fully matured grapes should be used for drying, otherwise there is marked decrease in yield and profit. Raisin grapes are dried in the vineyards. The rows of grapevines run generally east and west and between the rows there is sufficient space for the drying trays. In order to tilt the tray toward the south, a layer of soil is turned up with a plow on the north side of the row, upon which one side of the tray is rested. Bunches of grapes are cut from the vines with special knives and placed evenly in the trays one layer deep only. After the grapes have become partially dried (nearly a week and one-half is required in normal drying weather), they are turned. When the juice can no longer be pressed from the grape with the fingers, the trays are stacked to protect the grapes from the direct rays of the sun and permitted to continue to air-dry until the moisture content is about 17 per cent or lower. The raisins are then placed in sweatboxes for the sake of equalizing the moisture present in them.

Dehydration. (As applied to Thompson Seedless Grapes.)—Well-matured creamy to golden-yellow-colored grapes with a juice of at least

[1] For a full discussion of grape dehydration see P. F. Nichols and A. W. Christie, *Univ. California Agr. Exp. Sta. Bull.* 500, 1930.

23° Balling (sugar percentage) are used. The fruit is immersed in a lye, soda, or other alkaline solution, "dipped," at a temperature between 200 and 212°F. for 2 to 5 seconds. Dipping is done to remove dust and the waxy bloom of the fruit, thus making the skin more permeable, which facilitates the subsequent drying process, as by careful procedure the skin of the grapes is "checked" with numerous short shallow cracks. Careful regulation of the strength of the solution is necessary. The fruit is next sprayed with fresh cold water, sorted, and placed on trays. The trays of fruit are then loaded on cars which are run into small buildings, sulphur houses, and exposed to the fumes of burning sulphur for 2 to 3 hours. About 2 to 4 lb. of sulphur are burned per ton of fruit. The sulphuring process has the double purpose of bleaching the color of the grape and aiding in its preservation, but, owing to restrictions in various importing countries, the dried fruit should have a sulphur dioxide content between 200 and 1,000 parts per million. After the sulphur treatment, the fruit may be placed in the dehydrator immediately, or partially dried in the sun and then completed in the dehydrator.

Most raisins are dehydrated in tunnel dehydrators which are the most common type used in California and of which there are numerous makes. These may be heated by oil, gas, electricity, or other fuel, but in the grape regions oil is both cheap and easily available. The careful maintenance of accurate temperature and humidity control is most essential. The most efficient relative humidity is about 25 per cent. Optimum air velocity in the dehydrator is between 700 and 1,000 linear feet per minute between trays. The temperature during the latter part of the dehydration process should not exceed 165°F. The actual time required for dehydration depends on the load, temperature, humidity, air velocity, type of dehydrator, and other variables.

When the desired dryness of the fruit has been attained, it should be removed immediately, taken from the trays, regraded if necessary, and packed, preferably in boxes rather than bins because of damage incurred in handling in the latter case. Generally the moisture content should not be over 18 per cent.

The largest raisin-packing plant in the world, operated by a cooperative growers' association, is located in Fresno, California. In this plant raisins, both seeded and seedless, are further graded, sometimes seeded in special machines, processed, and packed in boxes or cartons for the retail trade. The seeded raisins are largely from Muscat grapes, while the seedless raisins, as stated above, are largely the Thompson Seedless.[1]

[1] Great care is necessary in the grading of raisins, by both chemical and physical methods to determine the comparative quality of the product. Various methods used for this purpose may be found in *U. S. Dept. Agr. Tech. Bull.* 1, 1927, Chace and Church.

VEGETABLE POWDERS AND FLAKES

Dehydrated vegetable powders and flakes are manufactured in one plant in California handling asparagus, beets, cabbage, carrots, cauliflower, celery, garlic, kale, lettuce, mint, parsley, okra, onions, rhubarb, spinach, tomatoes, turnips, watercress, chili, and pimento.[1] A part of these materials are sold to restaurants and packing houses, while others are used for flavoring materials and dietary preparations. The drying is accomplished by tunnel dehydrators which are gas-heated. About 30 per cent of the product is sold in powder form, which is obtained by the use of hammer mills. Tins of 5-gal. capacity are used for shipping both powdered and flaked material, the seal being made with solder and also by paraffin.

POTATO FLOUR

In Idaho[2] a part of the potato surplus is utilized to make spray-dried potato flour which may be used in the baking industry. The potatoes are separated from foreign material, washed, passed through a steam cooker on a conveyor belt, and subjected to superheated-steam cooking. From the cooker they are dropped into an extruder which removes the skins, and then into a tank where water is added to make a liquid. The hot liquid is sprayed by means of aluminum spray disks running at the rate of 8,000 to 10,000 r.p.m., atomizing the material into a very fine mist. This mist is discharged into a chamber within which a heated-air current at high velocity is maintained. The droplets dry almost instantaneously and the dried potato material drops to the floor, where it is moved or swept aside by the incoming stream of heated air which enters near the floor in pipes which revolve like those of a lawn sprinkler. Air collectors recover the potato particles in the air stream and conveyors transport the material to sifters. The system is capable of producing 1,000 lb. per hour.

SUGAR-BEET DEHYDRATION TO FACILITATE STORAGE

In 1925 a process was developed in England whereby sugar beets could be dried satisfactorily and stored in this condition for extended periods of time, thus increasing the period of operations during which the sugar extractions could be conducted from 3 to 4 months to 12 months.

The beets are cut into cossettes or small pieces, placed on a conveyor belt to a depth of about 7 in., and then dried in three successive stages, each of which is separated by air locks. The air enters the first stage where the raw material is initially treated at a temperature of 260°F. and the discharged air is about 120°F. In the second stage the entering air is about 230°F., and in the third or final stage it is at a temperature

[1] WHARTON, M., Dehydrating Vegetable Products, *Food Ind.*, **3**, 294, 1931.

[2] BOWEN, W. S., *Food Ind.*, **3**, 381, 1931.

of 180°F. The entire dehydrating time is 50 minutes, and during the first stage of 15 to 20 minutes about 65 per cent of the moisture is removed. The second or intermediate stage removes 25 per cent of the water, and the third stage the remainder.

The heating of the air, which is forced through the materials at different velocities in each stage, is accomplished by mixing atmospheric air with the gases from a coal furnace. It first is used in the third stage, then mixed with furnace gases and put through the second stage, heated again and forced into the first-stage compartment.

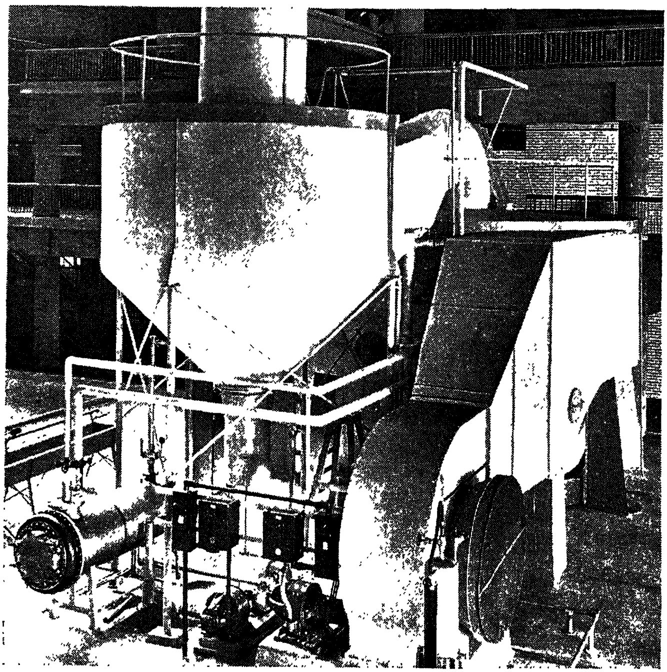

FIG. 62.—Yeast dehydrator. (*Courtesy of Food Industries.*)

The beets are reduced in weight by 75 per cent during the process and reduced about 50 per cent in storage volume. The latter may be further reduced by mechanical compression of the dehydrated product. This method was developed by the Institute of Agricultural Engineering at the University of Oxford.[1]

DEHYDRATED YEAST

A spray dehydrator for the commercial production of powdered yeast been in use for several years in St. Louis.[2] This equipment has a

[1] OWEN, B. J., *Food Ind.*, **1**, 699, 1929.
[2] FARRALL, A. W., *Food Ind.*, **3**, 513, 1931.

capacity of over 300 lb. of yeast powder per hour and dries the product to a moisture content of 3 to 4 per cent.

Compressed yeast is mixed with water and pumped through an atomizer directly into the drying chamber which is heated to between 225 and 290°F. by a stream of air furnished at the rate of 15,000 cu. ft. per minute. The air enters the drying chamber, which is in the form of an inverted cone 18 ft. in diameter at the top, and causes a high-velocity spiral current which is directed downward to the center, then turns upward, and passes out at the top. The dried powder drops to the sides of the drying chamber and is conveyed into the powder receiver by a pneumatic system. If the original liquid has less than 16 to 17 per cent solids, it is necessary to concentrate the material to that concentration, which is done by means of the still-hot-air exhaust from the drier, thereby conserving fuel and conserving the yeast powder in the exhaust air at the same time. The entire operation is completed from the liquid to the atomizer in less than 30 seconds. Allegheny metal was used for a part of the installation to avoid possible corrosion.

DRIED-EGG PRODUCTS

Dried-egg yolks in the United States are usually dehydrated by the spray processes. Dried albumin is produced either by spray methods or by the use of tray driers with a warm-air current.

Egg whites which have been fermented make a more satisfactory dehydrated product as such products have their main value in the characteristic of producing a tenacious and voluminous film when beaten or whipped.

DEHYDRATION OF DAIRY PRODUCTS

The dairy industries have been the greatest users of dehydration equipment as the production of dried-milk products, including whole milk, dried skim milk and dried buttermilk, have seen large increases since the years before the World War. Malted milk was the most important dried-milk product previous to that time and has increased somewhat in production but compared to dried whole milk, skim milk, and buttermilk, the increase is insignificant. The tonnage of dried whole milk has increased to about 5 times, skim milk to 15 times, and dried buttermilk to about 20 times the quantity manufactured 20 years ago.

The total quantity of dried-milk products produced in recent years amounts to about 170,000 tons, and represents more than a million tons of raw milk.[1]

[1] The methods used are discussed in the chapter on dairy products. See also A. W. Scott, Engineering Aspects of the Condensing and Drying of Milk. Glasgow, 1932.

originating the manufacture of sea salt in the Mediterranean and the Romans had a saltern near Ostia in about the seventh century B.C. The Romans also are credited with being the first to concentrate brine from salt springs in England for crude salt.

Solar Salt.—Thousands of tons of salt are still produced from the ocean waters along the coasts of France, Portugal, Turkey, Russia, India, China, the tropical islands of the Atlantic and Pacific, as well as the United States, where this is an important industry. This procedure is often one involving the use of natural means for the evaporation of water by exposure of the sea water to the sun and air in shallow pits or reservoirs after it has been impounded. This concentration of salt by natural evaporation may be supplemented by heat in modern manufacture or by the primitive method of pouring or spraying the concentrated brine on twigs or branches of trees from which the salt crystals subsequently formed may be scraped.

The manufacture of solar salt is particularly advantageous where the weather is hot and dry and where one can secure labor at relatively low costs. Unless the product is later refined or purified, the many impurities originally present in sea water may remain in sufficient quantities to make the salt objectionable for some purposes. Favorable winds are very helpful in attaining rapid concentration of solar salt. Palestine had its evaporating flats for solar salt along the shores of the Dead Sea, while the same principles using more modern methods are used today on the shores of the Great Salt Lake in Utah and in California where solar salt is an important industry.

The general method used on the Pacific Coast involves the evaporation of water in a series of connecting diked areas covering many acres.[1] Some of these plants are located in southern California while others are a few miles south of San Francisco on San Francisco Bay and use its waters. The water to be concentrated is allowed to enter by tide or is pumped into a tide pond where it goes through a preliminary settling process lasting for about two weeks, during which time some evaporation takes place and materials in suspension may settle out. It is then transferred to what are known as secondary ponds, usually at a higher level, and goes through a further concentration until a definite specific gravity is reached, when the gates are opened into further secondary ponds where calcium carbonate precipitates out of the brine. The next reservoir, where the brine reaches a specific gravity sufficiently high to precipitate the calcium sulphate is called the pickling pond. The next concentration area is in a sense the most important one, the crystallizing pond, where the salt crystallizes and forms a precipitate on the clay floor of the basin. Here

[1] For an extended discussion of salt manufacture, see D. K. Tressler, Marine Products of Commerce, 1923.

the brine is allowed to remain until a concentration is reached which approaches the crystallizing point of magnesium sulphate. Previous to this point, however, the remaining mother liquor or bittern is drawn off, as magnesium sulphate is undesirable in high-quality salt. After a number of inches of salt has accumulated as a layer on the floor of the crystallizing pond, it is plowed up and stacked by tractors, or by shovels and wheelbarrows if manual labor is utilized. The salt is later conveyed on narrow-gauge tracks to the plant for further treatment which may consist of crushing and grading by size or subsequent refining processes. The bittern or mother liquor may be used for the recovery of magnesium sulphate, magnesium and potassium chlorides, and other salts, but in some instances it is allowed to flow back into the ocean.

Sea solar salt is likely to contain in addition to chemical impurities various salt-tolerant or halophilic microorganisms, particularly the higher bacteria, which may produce red discolorations on saltfish or hides cured with salt from that source.[1] Mined salt is generally free from these organisms unless it has been mixed with sea salt.

Mined Salt.—There are extensive underground deposits of salt which are of commercial importance in many countries. One of these at Wieliczka, once a part of Austria but now in Poland, is said to spread over an area of 12 square miles. Others exist in Cheshire, Yorkshire, and Worcestershire in England, Stassfurt in Germany, Cordona in Spain. In this country similar deposits are located in New York, Ohio, Michigan, Louisiana, and Kansas. In Nova Scotia a deposit of rock salt was discovered in 1912 and has been worked commercially since 1919.[2]

The deposits are sometimes more than 1,000 ft. below the surface of the earth and in some instances the crude salt is sawed in large blocks, then blasted with dynamite. It is later reduced to smaller sizes and conveyed to the surface by hoists, where it is further crushed, screened, and sometimes refined. This type of salt is the source of rock salt which is used extensively in the packing industry for curing meat and salting hides and for livestock salt. It may also be used for many other industrial purposes including tanneries, chemical plants, refrigeration purposes, etc.

Salt from Wells.—In many subterranean salt deposits it has been found more advantageous to bring the salt to the surface as a brine, in which case shafts are drilled and pipes sunk to the salt-containing strata which may be 1,800 ft. or more below the surface. Within the outer shell is a system of pipes through one of which water may be pumped down into the salt-containing layers where it dissolves salt in the deposits and

[1] STUART, L. S., P. W. FREY, and L. H. JAMES, *U. S. Dept. Agr. Tech. Bull.* 383, 1933.

[2] COLE, The Salt Industry of Canada, Canada Dept. Mines, No. 716, 1930.

becomes brine. This brine is then pumped or forced by air pressure to the surface within another pipe in the same casing. The solution is allowed to stand in tanks for a few days, permitting impurities such as the sulphates of magnesium and calcium to settle out before further processing.

Salt Refining.—There are two different methods by which the brine may be processed, one being the vacuum-pan system. When this system is used, the brine is pumped to large vertical vacuum pans, which are sometimes in multiple effect in order to be more efficient from a thermal standpoint. Here it is heated by steam and subjected to a reduced pressure in order to evaporate the water. At intervals the concentrated salt is removed from the base of the vacuum pan, then filtered or centrifuged to remove excess moisture, and finally dried in rotary driers or kilns maintained at temperatures of about 350°F.

The open-grain method requires the use of relatively shallow pans into which the brine is pumped and heated by means of steam coils to a temperature of about 195°F., in order to form large-sized salt flakes. During the crystallization the brine is not disturbed and the small crystals which first form grow in size until they are finally deposited at the bottom of the tank. By means of automatic rakes the crystals are scooped up an incline and are conveyed to washers, thence to driers where the remaining moisture is removed.

The size and shape of crystals or "grain" of the salt resulting from evaporation and crystallization processes are dependent on the temperatures employed. It is obvious that such temperature control is not possible in the manufacture of solar salt, but in the vacuum pans and the grainer process much more uniformity of product may be attained. Salt made by the vacuum process is usually fine in grain and relatively uniform. Salt is screened to separate it into different-size grades as the uses of the product depend in part on the grain of the salt.

Automatic packaging equipment by means of which the product is packed in barrels, bags, or cartons is used in most of the large salt-manufacturing plants. Some salt is pressed into large blocks under great pressure to be used for cattle, in place of rock salt.

Some table salt for domestic use is treated with small quantities of iodine salts in order to supply iodine, as goiter, a disease due to a dysfunction of the thyroid gland, may be caused by a deficiency of iodine. Salt may have small quantities of inert materials or other chemicals such as calcium carbonate added in domestic packages, to prevent sticking in damp weather.

The uses of salt are widespread. Foremost among its uses is that of a seasoning material for food and as a food preservative. It is used for curing meats and fish, in the pickling industry, the manufacture of butter,

oleomargarine, cheese, and many packing-house products. Salt is used as a stockfeed and in the making of ensilage and curing of hay. It attains great usage in the tanning industry, in the refrigeration industry as a refrigerant, and in the manufacture of pharmaceutical products and soaps. Salt is one of the basic raw materials used in the manufacture of many chemicals and serves usefully in metallurgy.[1]

In 1933 the salt production from mines, wells, and ponds in the United States amounted to over 7½ million tons and had a value of more than 22 million dollars. Rock salt made up 23 per cent of the output, evaporated salt about 31 per cent. There were 72 plants operating in this country for the production of salt in that year, and approximately 46 per cent of the total salt production was used in the manufacture of chemicals. The salt evaporated in open pans or grainers was about twice the quantity of solar evaporated salt, and approximately half the volume of salt evaporated in vacuum pans. Michigan is usually the largest producer of evaporated salt, followed by New York, Ohio, California, and Kansas.

The importation of salt in recent years amounted to about 30,000 tons while the exports in 1933 were over 100,000 tons, Canada taking about one-half.[2]

The Use of Salt in the Salt-fish Industry.—The salt-fish industry uses large quantities of salt and the kind of salt utilized has much to do with the quality of the finished product.[3] Salt high in magnesium or calcium salts or sulphates are likely to produce inferior products as they tend to retard the penetration of sodium chloride into the tissues and may cause bitter tastes. The use of salt of high purity is particularly desirable in warm weather and with fish which have not been salted immediately after being caught. Ordinary pure sodium chloride develops a salted product which is relatively soft and light yellow or creamy in color. When soaked in water, it is capable of being brought back to a condition comparable to fresh fish. Calcium and magnesium impurities in concentrations as low as 1 per cent are likely to cause excessive stiffening of the fish and result in a white color. Sulphates are not often present in concentrations sufficient to cause trouble.

Fish-salting Methods.—There are two general methods of salting fish, dry salting and brine salting. Dry salting is accomplished by packing the fish in alternate layers of salt after the fish have been dressed and cleaned. Dressing involves beheading, splitting, removing the entrails, etc., unless the fish are salted whole or "in the round." Salt is used to the extent of

[1] Salt Empire, International Salt Co.

[2] For more detailed statistics concerning salt see Minerals Yearbook, 1934, U. S. Dept. of the Interior. Chapter by A. T. Coons, pp. 929–945.

[3] TRESSLER, D. K., *U. S. Bur. Fisheries Rept.* 1919, App. 5; also Doc. 884, 1920.

about a third the weight of the fish, depending on the temperature and other factors such as the kind and size of the fish. The fish and salt are generally piled up in barrels, tierces, or watertight containers, and as water is extracted from the fish, a brine is formed which eventually permeates the fish tissues completely. After the salt has "struck in" or permeated throughout, the fish may be packed in fresh brine or removed for drying on the flakes—low platforms made of slats which make it possible to expose the fish to the outer air and sunlight.

The brine method is used for alewives or river herring and similar fish. It involves filling vats or barrels to a definite level with brine of a definite salinity and immersing the fish in this brine. Agitation is necessary at intervals to keep the brine uniform in composition.

During hot weather or in tropical climates particular care must be taken to accomplish salting without spoilage. Tressler has shown that better results are obtained if fish are thoroughly cleaned and all the visceral organs and blood removed, including the milt and roe. It is also essential that salt of high quality be used under these circumstances.

Difficulties Encountered in the Handling of Salted Fish.—Much spoilage is encountered with salted-fish products because of chemical and biological changes that may occur. Some of the reactions are the result of autolytic changes due to enzymes which are inherent in fish tissues. Others are due to the activities of bacteria which are present, and which are very numerous if the product has been carelessly handled previous to salting. Salt acts as a retarding agent in both instances, but it requires time for sufficient quantities of salt to penetrate the tissues and build up inhibitive concentrations. In warm weather the rate of enzymic and bacterial changes is more rapid, and the damage may be lessened by using lower storage temperatures when possible.

With oily fish there is likely to be a change in the fat-containing tissues, which results in conditions such as rancidity and "rusting." The fats become oxidized and the end products of the oxidation reactions are substances which spoil the flavor. The tuna fish is said to be particularly susceptible to such changes, although they may occur in herring and mackerel. The action of light, the presence of oxygen, and certain metal catalysts all tend to accelerate this type of chemical action. Rusting is attributed to the action of enzymes in the blood and is thought to be accelerated by impurities in the salt used in curing. Careful cleaning of the fish is helpful in lessening this trouble.

Another type of trouble associated with the storage of salted cod and similar fish is the appearance of a reddish pigment ranging from pink to brick color on the surface of the flesh. This is due to halophilic ("salt-loving") microorganisms which are often found associated with sea salt or solar salt and will grow only in its presence. The use of mined

salt, which has been found free of these microorganisms, will eliminate this difficulty if precautions are taken to prevent contamination by other salt previously used in the same plant. Boric acid is sometimes added in small quantities to lessen the incidence of reddening. It may be carried out by mixing the dry boric acid, 0.4 per cent by weight of salt, with the final salt. This mixture is then used when the salted codfish is packaged or packed for shipment, but such practice is not allowed in all states owing to different state laws concerning preservatives.

SAUERKRAUT

The sauerkraut of today is a product resulting from a bacterial fermentation of cabbage, during which lactic acid is produced in sufficient quantities to act as a preservative against putrefactive change as well as creating a part of the desired flavors. It has been a popular food in Europe for at least 400 years, and probably had as its antecedent the somewhat similar preserved cabbage soaked in sour wine or vinegar which was popular even before the Christian era. The present name is of German origin, and this product has always been highly esteemed by the Germans, to whom it is the national dish.

Sauerkraut is an important article of food which has attained wide consumption and production because of its taste appeal as well as its economy. It serves as a means of conserving the thousands of tons of cabbages annually which may be readily grown in many areas. From a domestic product made in the home it has become a commercial industry, having a value of bulk products approximating $2,700,000 and canned products $5,200,000 in 1933, according to the United States census reports. The industry is now largely localized in the North Central states, especially those bordering on the Great Lakes in this country, but some of the largest plants are in western New York.

The cabbage varieties best suited for sauerkraut, according to LeFevre, are All Seasons, Glory of Enkhuizen, All Head Early, Flat Dutch, and Copenhagen Market. Firm, compact heads which are not colored are most desirable. It is important that immature and partially decayed material be rejected because it would result in an objectionable product. Because of these requirements sauerkraut manufacture is a seasonal industry which generally extends only during the last four months of the year.

When the cabbages are harvested, care is taken to prevent injuries by avoiding the use of metal forks for handling, and after harvest the heads are stored long enough to allow the outer leaves to wilt before the cutting operations are started. This may take place outside the packing house, or in special wilting or sweating bins where the temperature may be

advantageously controlled. By wilting, the leaves become less brittle; and finer, long shreds may be cut which result in a product of better texture and more uniform appearance. At the same time the temperature of the cabbage is usually raised to at least 70°F.

The first actual plant operation is to remove the core or main stem of each cabbage by a coring machine. Some machines are designed to cut out the interior of the core although this is not necessary. After coring, the outer, green, coarse leaves, and all dirty or bruised portions are removed by women trimmers, and the trimmed heads are conveyed to the cutters. The cutters are mechanical devices into which the cabbages are fed so that they come in contact with a series of curved knives mounted on a rapidly revolving horizontal disk and capable of cutting the wilted cabbage into shreds as fine as $\frac{1}{32}$ in. in thickness.

The cutting machines, which may have a cutting capacity of many tons of cabbages a day, are usually located on an upper floor in the plant so the resulting shreds may fall on a conveyor belt or into a hand cart, by means of which the shreds are conveyed to the vats. The use of push carts appears to be preferable as they can be kept in a more sanitary condition and enable better packing of the cabbage in the vats and more uniform distribution of the salt.

The shredded cabbage is eventually placed in large tanks or vats where the fermentation process takes place. These fermenters may have a capacity of 25 to 70 or more tons of cabbage and are constructed of wood which may be lined with paraffin to prevent any woody flavors in the product. Some have been constructed of concrete. Regardless of the size or construction of the vats, it is essential that they be thoroughly cleaned before any cabbage is put in them.

Salt plays an important part in the making of sauerkraut and either before the shredded cabbage gets to the vats or when it is packed in the vats, salt is added in definite proportions. The amount of salt used varies in different plants but is almost always between 2 and 3 per cent, with 2.5 per cent the more common concentration. The higher limit of concentration is likely to retard the development of acidity and cause pink discoloration, while the lower concentration favors slimy kraut, as the fermentation is not so carefully controlled. The use of salt is important for several reasons. It tends to extract water from the cells of the shredded cabbage by osmosis, thereby facilitating the development of a brine. The presence of salt in suitable concentrations suppresses the growth and activities of undesirable types of bacteria which might spoil or lower the quality of the product. It sets up conditions which favor the development of the particular group of bacteria (lactic acid producers) which are essential for proper fermentation. Salt also contributes to the flavor of the final product in which a certain salinity is desirable.

During the filling of the vats care must be taken to have a uniform distribution of the salt and cabbage. In some plants the mixture is packed firmly in the vats by having men tread down the cabbage by walking around in specially cleaned rubber boots while the vat is being filled. When the vat is completely filled a heavy fitted cover of planks is placed on the material and heavy weights added so that a pressure of several tons may be exerted. Within a few hours a brine is formed which will be sufficient in volume to reach the surface of the cover.

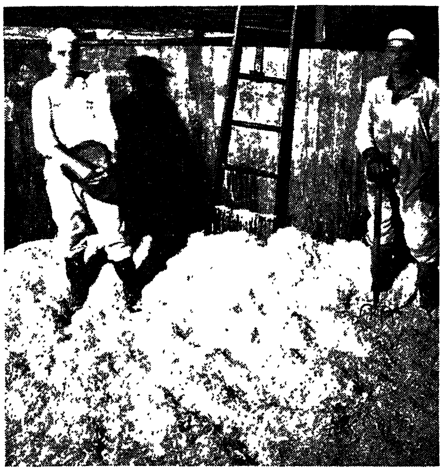

FIG. 63.—Distributing salt and packing shredded cabbage in sauerkraut vat. (*Courtesy of Food Industries.*)

The fermentation starts soon after the cabbage is placed in the vats. Several factors limit the intensity and duration of the fermentation, but the most significant of these, other than salt concentration, is temperature. There is some difference of opinion concerning the optimum. Temperatures as high as 86°F. were advocated by LeFevre, late of the U. S. Department of Agriculture, but temperatures in the sixties are preferred by some commercial packers. The time of fermentation is much shorter at the higher temperatures, which may be helpful if the vats must be used to greatest advantage from a production-capacity standpoint, but many packers believe lower temperatures and longer fermentation are likely to result in products of a higher quality. European practice favors lower temperatures, longer fermentation, and lower salt concentrations.

The fermentation is dependent on the types of bacteria present on the cabbage which are capable of developing and acting on the chemical components of cabbage juice in the presence of salt. Experiments have

been tried using pure bacterial cultures, but this practice is not used commercially. The bacterial flora of the kraut have been found to change during the course of the fermentation. During the earliest stages the original cabbage microorganisms which are not active acid producers appear to give way to a group of gas-forming cocci, chief among which is *Leuconostoc mesenteroides*. Lactic acid is produced to the extent of less than 1 per cent, along with small quantities of alcohol, mannitol, acetic acid, and some carbon dioxide. This group is subsequently replaced by the lactobacilli which are the principal organisms in the kraut fermentation. They utilize the mannite, or mannitol, present and are chiefly responsible for the final concentration of lactic acid, which may reach 1.8 per cent. Other compounds such as those already mentioned, succinic acid, aromatic esters, etc., are found in the final product and contribute to the characteristic flavor of the product.

During the fermentation there is a reduction in the mass of cabbage in the vats and the surface of the cabbage mass is normally below that of the extruded juice or brine. Although the lactic fermentation is anaerobic in character, there may appear on the surface a film or mycoderma, due to aerobic yeastlike forms which are capable of utilizing lactic acid for their own sustenance. Such films should be removed immediately, as by lowering the concentration of lactic acid which serves as a preservative for the finished kraut they may leave the product subject to putrefactive changes. Removal can be effected by skimming off the top, or the film may be largely prevented by keeping on the surface a layer of inert oil which shuts off the air and retards the growth of Mycoderma.

When the fermentation is completed, the juice is drawn off from the bottom of the vat and the kraut removed by forks. The juice may be recombined in definite proportions with the solid kraut and packed in barrels, tubs, kegs, and other containers for distribution. If it is not needed at once for distribution, there is less opportunity for spoilage if left in the fermenter, provided this is practicable. An increasing amount of sauerkraut is being canned, as this affords a means of convenient handling and assures permanent preservation until needed for consumption. Sauerkraut juice itself has been packed in cans and marketed as a drink in the same category as tomato juice; but it has a relatively restricted consumption.

The Federal definition of sauerkraut is as follows:

> Sauerkraut is the product, of characteristic acid flavor, obtained by the full fermentation, chiefly lactic, of properly prepared and shredded cabbage in the presence of not less than 2 per cent nor more than 3 per cent of salt. It contains, upon completion of the fermentation, not less than 1.5 per cent of acid, expressed as lactic acid. Sauerkraut which has been rebrined in the process of canning or repacking, contains not less than 1 per cent of acid, expressed as lactic acid.

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VINEGAR

Vinegar is an important condiment and preservative which is produced through the action of acetic acid bacteria on dilute solutions of ethyl alcohol derived from a previous yeast fermentation.

According to the United States Department of Commerce, the annual value of commercial vinegar production was over 5 million dollars in 1931 and exceeded 9 million dollars in 1925, exclusive of tremendous quantities made on farms, in small establishments and as a secondary product by canning establishments and evaporated-apple manufacturers.

Vinegar is a product of ancient origin, probably of equal antiquity as wine, because sour wine and vinegar are practically identical and the term vinegar itself has that significance in the French language. It may also be produced from fermented cider, fruit juices, or other fermented alcoholic solutions derived from barley malt, hydrolyzed cereals, and starches, or other carbohydrates. It may also be produced from diluted ethyl alcohol obtained from other sources, provided the concentrations are within certain limits. In all cases, however, the actual chemical changes taking place are due to the activities of the acetic acid-producing bacteria, the most useful species in this respect being *Acetobacter aceti.* Other species are *A. pasteurianum, A. kutzingianum, A. xylinum, A. acetigenum, A. oxydans* and *B. industrium,* but some of these are so vigorous in oxidizing action that they burn acetic acid to carbon dioxide and water.

In most instances the flavors and odors of the final product depend in part on the materials used as the source of the alcohol which the acetic bacteria oxidize to acetic acid, together with additional flavors developed during the alcoholic fermentation by yeasts, and the subsequent acetic fermentation.

These fermentations may go on spontaneously in fruit juices because the yeasts and bacteria capable of bringing about such changes are normally present on the fruits. In commercial operations the fermentations are usually controlled to a large extent by the use of added yeast cultures and later utilization of favorable types of vinegar or acetic acid bacteria, together with the adjustment of temperature and oxygen relations to obtain best results. They must occur, however, in definite sequence as the acetic acid bacteria act on the alcohol from the yeast fermentation, and unless the alcohol is formed, there can be no acetic acid developed. As acetic acid in even low concentrations tends to inhibit yeast fermenta-

tions, it is also undesirable for these bacteria to start their activities until the yeast fermentation is completed.

The alcohol-producing yeast best suited for the first fermentation is *Saccharomyces ellipsoideus*. In large-scale operations the carbohydrate-containing solution is usually inoculated with sufficient quantities of this yeast as a starter to dominate any other yeasts which may be present in the original solution. Many wild yeasts produce abnormal fermentations and lower both yield and quality. When possible, the temperature of the fermenting material is kept above 70°F. and the fermentation allowed to go on until the sugar has been entirely utilized. When the conversion of sugar to alcohol by the yeast has been completed, it is advantageous to have the vinegar fermentation follow as soon as possible thereafter, as other microorganisms likely to be present may utilize some of the alcohol, thereby lowering the yield, or may produce undesirable flavors. As many such organisms are aerobic, they may be checked by putting a thin layer of oil on top of the storage tanks if a delay must ensue.

Cider Vinegar.—The manufacture of cider vinegar requires the preliminary grinding and pressing of sound apples, the expressed juice from which contains the sugars serving as the basis for the alcoholic fermentation. The original sugar content of the apples is of importance because the yield is directly dependent on this content. To get the highest yields of sugar, some manufacturers extract the pomace with water and subject it to one or more subsequent pressings.

The must or vinegar stock, as the sweet cider is often called, is generally run into large vats, the seed culture of yeast is added, and the fermentation allowed to go on for the necessary time. This may require several weeks depending on temperature. There is usually a rise in temperature during the fermentation which may be controlled if necessary by the use of cooling coils in the vat. Yeast grows actively up to 85 to 90°F. The higher the initial temperature, the more rapid and violent the fermentation and the sooner it is completed.

The yeast fermentation proceeds under anaerobic conditions, but the subsequent acetic fermentation requires oxygen or air in order to be successful, as the conversion of ethyl alcohol to acetic acid is an oxidation depending on the ability of the oxidizing enzymes of bacteria to utilize the free oxygen. There are numerous ways of accomplishing this. On the farm it may take place by leaving the bung out of the barrel. The conversion is accelerated by having the barrel on its side with numerous air-inlet holes bored in the topmost side and the barrel only partly filled with fermented cider, thus leaving a larger surface area of the liquid in contact with air. These methods, while satisfactory for home purposes, are too slow for commercial operations which are carried on in a manner enabling larger quantities to be handled in a relatively short time.

The so-called rapid method, using a vinegar generator, involves several factors, each of which tends to increase the rate of conversion of alcohol to vinegar. These generators are tall truncated cones or vertical wooden tanks having a false bottom, and which are filled with hardwood shavings, split rattan wound on poles, or some other material having a very large surface area and many small voids. The alcoholic solution is introduced intermittently from the top and allowed to drip through the filling where it comes in contact with the surface of the rattan or shavings which have previously been soaked in high quality vinegar and thus have a generous inoculant of the desirable types of acetic acid bacteria. At the same time sufficiently large quantities of air are admitted through holes in the false bottom and inlets in the tank planks, so that there will be a constant supply of air rising countercurrent to the solution trickling down. It is customary to mix the alcoholic cider with a certain proportion of vinegar before introducing the fluid into the generator to make the solution of optimum acidity for the conversion. In this way it is possible to set up very favorable conditions for the oxidation. In trickling through the length of the tank each particle of solution comes in contact with millions of bacteria covering the rattan which has a great surface area and the temperature can be controlled by governing the air flow. Heat is generated by the biological process, as the oxidation is an exothermic reaction, so the air rises in a stack effect. Excessive heating above 95°F. is undesirable because acetic acid is volatile and large losses may result, but it is possible to cool the solution before use or increase the air flow somewhat if necessary. The effluent from the generator may be run through again if not completely acetified, or used to mix with an alcoholic solution and the operations completed in a second generator.

The generator method, after it is once started, may be run continuously for long periods of time provided the bacteria do not grow sufficiently to interfere with the flow of the liquid. By filtering the cider before introducing it into the generator, this film development is retarded. When it has developed to an excessive extent, removal of the top layers in the generator and replacement by new filler will remedy the difficulty.

Other Vinegars.—Grapes are used for vinegar making on a large scale on the Pacific coast. Grape vinegar is popular in some districts, especially among European peoples, as wine vinegar is almost exclusively used in Europe. Grain or spirit vinegar may be made using sugars, sirups, or molasses as the carbohydrate material which serves as a source of alcohol fermentation. After the yeast fermentation, the fermented material may be run directly into the generators or may be converted into "low wine" by low-pressure stills and then sent to the vinegar generators. In the former case the product may be known as sugar vinegar. Malt vinegar is produced by using barley malt in combination with corn or other cereals as a source of carbohydrate. The ground mixture is mixed

with water and kept at about 130°F. for a few hours to enable complete hydrolysis of the starches, then pasteurized, cooled, fermented by yeast, again pasteurized, filtered, and finally run into the generators.

Vinegar is sometimes infected with small parasites called vinegar eels, *Anguillula aceti*, which often develop in the generators. They may be removed by filtration or killed by pasteurization temperatures. Vinegar flies, *Drosophila* spp., are sometimes encountered in vinegar factories but can be controlled by careful sanitary measures or fumigation. Vinegar mites, *Tyroglyphus*, are also encountered and are subject to similar treatment. If vinegar is stored for periods of a few months or longer, improvements in flavor occur owing to the formation of esters. The temperatures preferred for storage are between 40 and 50°F.

After treatment the finished vinegar may be packed in barrels, jugs, or bottles. As it usually contains sediment and suspended material and has large numbers of bacteria, filtration and clarification processes similar to those used for fruit juices are employed. Some filters remove practically all the bacteria.

In order to prevent further growth of vinegar bacteria and film or mother development, as the vinegar bacteria are generally encapsulated organisms, the product is commonly heated or pasteurized. This is always done if the product is to be packed in glass. A recent method of treatment advocated for this purpose is the use of silver which is introduced by passing the vinegar through an apparatus having exposed electrodes of silver through which a small current is passed. The development of acetic bacteria may also be checked by sealing containers so that the entrance of air is excluded.

A type of vinegar generator has been introduced in recent years which is a closed system, the air being introduced under pressure. The maintenance of temperature is accomplished by recirculating a part of the solution and cooling it by mechanical refrigeration to the extent desired. Cold-water coils may be used for the same purpose.

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PICKLES

The production of pickles from cucumbers has become an industry of considerable importance. According to Beattie,[1] some 4 million bushels of cucumbers are raised for pickling purposes each year. About

[1] Beattie, J. H., *U. S. Dept. Agr. Farmers' Bull.* 1620, 1930.

half of these are produced in Michigan and Wisconsin, while other large producing states are Indiana, Minnesota, Colorado, California, and Ohio. The principal varieties of cucumbers grown for this purpose are Snow's Pickling, Chicago Pickling, Boston Pickling, and Jersey Pickling, all of which are capable of growing to a length of 5 to 7 in. but are most desirable when harvested at a length of 3 in. or less.

Pickling cucumbers are subject to two insect pests which cause considerable damage: the striped cucumber beetle and the melon aphid. They are also subject to a number of diseases including bacterial wilt, mosaic, anthracnose, scab, and angular leaf spot. Downy mildew and root knot, which are caused by nematodes, are troublesome in the Southern areas.

Those areas specializing in the growing of cucumbers for pickling purposes are usually near salting stations owned by pickle manufacturers who frequently contract with growers in advance for their crop and furnish the seeds in order to obtain the types most desirable for their purposes. At these salting stations the cucumbers, which are usually picked when underripe, are placed in a brine and allowed to undergo a lactic acid fermentation through the action of bacteria normally present. The concentration of this brine in which the cucumbers are submerged is about 10 per cent salt at the start. This is sufficient to prevent undesirable putrefactive microorganisms from developing and yet will not inhibit the lactic acid types. During this fermentation which lasts for several weeks the sugar in the cucumbers is almost completely utilized and at the same time the cucumbers absorb salt from the brine. It is essential during this period that surface films of Mycoderma should be removed as these organisms tend to utilize the lactic acid which is distinctly undesirable. When the pickles are put in a 10 per cent brine, 9 lb. of salt per 100 lb. of pickles is added and each week the brine is increased gradually until the brine reaches 15 per cent salt. This method is known as high-salt curing, under which circumstances firmer and better products result, although the fermentation proceeds more slowly. Some manufacturers use an initial salt concentration of about 8 per cent, which permits more rapid curing and fermentation but offers greater probability of abnormal fermentations and therefore is generally confined to periods of cooler weather.

Salt plays an important part in the pickling process. It sets up osmotic processes which withdraw some of the water and soluble nitrogenous and carbohydrate materials from the cucumbers. The concentration of salt makes a great difference in the appearance of the pickle, however, as when high concentrations of salt are used a shrinking or shriveling results. Only high-quality salt should be used in making the brines as the impurities in low-grade salt are likely to be harmful. Experi-

ments conducted by Fabian and his colleagues[1] have indicated the possibility that chlorine treatment of cucumbers previous to pickling may be helpful in cutting down the incidence of undesirable bacteria, although if too high concentrations are used, both the putrefactive types and the necessary lactic acid-forming types are inactivated or killed.

The pickles produced in the manner outlined will keep for considerable periods of time, but they are too highly salted for table use. When they are to be used for the making of sour pickles, sweet pickles, or mixed pickles, they are first soaked in hot water in order to decrease the salt content to the desired stage and the vinegar or other final solution is added. As many types of pickles are packed in definite grades, the sorting according to size usually follows the removal of excess salt. The irregular-shaped pickles are usually cut up and used for one of the components of the mixed.

Dill Pickles.—One popular type of pickles on the market is known as dill pickles. These are produced by placing cucumbers in a brine of lower salt concentration containing dill and sometimes other spices. The fermentation under these circumstances is much more rapid and the possibility of spoilage is increased to a great extent. Joslyn has recommended the addition of sugar to the brine to decrease the development of slippery pickles.[2] Fabian and Wickerham have found that adding sufficient acetic acid to produce an initial pH of 4.6 in the dill-pickle brine is helpful in this type of fermentation which they found to consist of three different phases.[3] The first phase is due to gram-positive cocci, which are replaced by short rods that are mainly gram-positive. Long gram-positive rods predominate during the latter part or third phase of the fermentation. They also found that the addition of sugar to the extent of 2 lb. per barrel was helpful.

Most of the pickles packed in small-sized domestic packages are in glass jars and contain sufficient concentrations of vinegar (distilled) to preserve them until used, although they may be packed in heavily lacquered cans, according to Cruess.[4]

According to the U. S. Department of Commerce census of manufactures for 1931, the value of manufactured pickles for that year was over 28 million dollars. Illinois, Pennsylvania, California, Wisconsin, and Michigan were the most important manufacturing states. Others of importance were New York, Iowa, and Ohio.

[1] Fabian, F. W., C. S. Bryan, and J. L. Etchells, *Michigan Agr. Exp. Sta. Tech. Bull.* 126, 1932.

[2] Joslyn, M. A., *The Fruit Products J. Am. Vinegar Ind.*, **8**, 19, 1929.

[3] Fabian, F. W., and L. J. Wickerham, *Michigan Agr. Exp. Sta. Tech. Bull.* 146, 1935.

[4] Cruess, W. V., Commercial Fruit and Vegetable Products, 1924.

TOMATO CATCHUP

Tomato products constitute a popular and important part of the nation's food. Over a million tons of tomatoes are used annually for the production of canned tomatoes, catchup, tomato juice, and pulp. Catchup is the most widely used spiced tomato product and has an annual production valued in some years at more than 15 million dollars. New York, Indiana, Ohio, and California are usually the foremost catchup-producing states and together manufacture about two-thirds of the annual production of the United States.

According to Federal definition, "Tomato catchup is the concentrated product made from the pulp and juice of ripe tomatoes (exclusive of skins, seeds, and cores), vinegar, salt, spice, and other seasoning, sugar and/or dextrose."[1] The same product is also designated as ketchup or catsup by others, although catchup is the more widely used term.

Selection of the proper fruit is of great importance in making high-grade catchup. Smooth-skinned varieties of tomatoes with firm flesh, deep-red color, and shallow stem cavities are considered most desirable for this purpose. The color is of particular importance as the red pigment of tomatoes, lycopin, may bleach to a yellowish color if not properly handled. Unripe tomatoes are not desirable, for the chlorophyll in the green portions tends to turn brown during cooking and detracts from the desired red color.[2]

Tomatoes should be carefully sorted, then washed thoroughly and trimmed if necessary. The tomatoes are next cycloned to produce pulp. This process crushes the fruit and separates the seeds, skin, and fiber. It may be done without previously heating the tomatoes, although by a slight preliminary heat treatment it is possible to inactivate enzymes and minimize chemical changes which may unfavorably affect the pectin constituents of the juice.

The juice from the cyclone may be immediately made into catchup or canned and used later. If it is to be canned as pulp for future use, it may be concentrated and then canned. Concentration of the pulp for catchup may be carried on in open kettles heated by coils or steam-jacketed kettles or in vacuum pans. Vacuum has the advantage of preserving flavor and color to a much higher degree than open-kettle cooking, owing to the already mentioned change of lycopin on prolonged heating. Iron and steel should not be used for equipment for handling tomato pulp, for the iron salts combine with the tannin extracted from the spices to produce black iron tannate. Iron also causes the browning of tomato pigments.

[1] S.R.A.F.D. 2, Rev. 4, August, 1933.

[2] See MacGillivray, J. H., *Indiana Agr. Exp. Sta. Bull.* 350, 1931, for color measurement discussion.

Copper also is believed to have an injurious effect upon the color. Glass-lined kettles for catchup manufacture are satisfactory, also equipment of monel metal, silver, nickel, tin, bronze, or Allegheny metal. Wooden tanks are more subject to mold contamination and must be kept strictly clean, if used. Rapid concentration preserves the color and flavor of the fresh tomato much better than slower heating.

The spices may be previously extracted in vinegar or directly in the boiling catchup. Some manufacturers use volatile spice oils instead. In the former method the spices (headless cloves, cassia, pepper, cayenne pepper, ginger, mustard, cinnamon, mace, etc.) are placed in the distilled vinegar (100-grain or 10-per cent acetic acid content), and steeped for 2 or more hours at a temperature a little below the boiling point. The vinegar containing the extracted spices is then added to the concentrated pulp or "puree." If the ground or whole spices are to be extracted in the boiling pulp, they are suspended in a cloth bag while the batch is in the kettle. Onions and garlic are often used for flavoring purposes and may be similarly treated. Spice oils which are generally in the form of emulsions are added at a later stage in the process when they are used, as the losses due to volatility would be great otherwise.

Salt and sugar are also important ingredients of catchup. The salt is usually added early in the heating process to assure perfect mixing and may be used in proportions up to 3 per cent of the finished product. The sugar and vinegar are commonly added toward the end of the cooking process as the sugar may caramelize with prolonged heating and the vinegar volatilizes readily.

The extent of the cooking depends on the consistency desired in the finished product, also on whether it is to be subjected to further heat treatment in the final container. As heating for prolonged periods is likely to affect color, it is necessary to determine when the process can be terminated. This point may be determined by a test for specific gravity or through the use of a refractometer which enables the determination of total solids more rapidly.

The cooking process is primarily for the purpose of concentrating and intermingling the various ingredients of catchup, although it also cuts down the numbers of microorganisms present. If the product is to be bottled without preservative, its total solids should be in the vicinity of 30 per cent and its acidity greater than 1 per cent.

When the cooking process is finished, the catchup may be run through a screening device or finisher to remove any aggregations of material. It is usually bottled while still hot. Bottles are the more common catchup containers, although jugs and lacquered cans may be utilized. If the containers are filled and sealed at temperatures of 175°F., or higher, further heat processing is generally unnecessary. Otherwise it is desir-

able to have a subsequent heat treatment. Preservatives are not commonly used in the higher grade products of this nature today.

According to Pederson and Breed,[1] the spoilage which occurs most commonly in canned tomatoes and tomato products, including catchup, is usually caused by various species of nonspore-forming rods or cocci of the genera Lactobacillus or Leuconostoc, although occasionally yeasts and spore formers are found in such spoiled products. Spoilage of this nature may be lessened by more careful attention in the sorting and trimming operations and by proper heat treatment, as the causative microorganisms are not of high thermal resistance. The products of such spoilage are not dangerous from a health standpoint but may cause off-tastes which are undesirable. Cooling of the finished product before storage is recommended to prevent stack burning.

The government control of catchup includes the use of the Howard method for the microscopic estimation of microorganisms present.[2,3] This method may also be used in the laboratory for control over operations in the plant, as it offers an indication of the care used in sorting. A detailed discussion of this method may be found in The Microbiology of Foods, by F. W. Tanner.

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PICKLED OLIVES

There are several processes employed for the pickling or curing of olives. Most of these are European in origin. Cruess[4] lists six processes which are practiced in the Mediterranean countries, namely:

The Spanish green-olive process.

The French process.

The brine process.

The dry-salt process.

The water process.

The Italian dried-olive process.

Olives for green pickling are picked in the United States when they show the first blush of color.[5] If the fruit is allowed to become fully

[1] Pederson, C. S., and R. S. Breed, *New York State Agr. Exp. Sta. Bull.* 570, 1929.

[2] Howard, B. J., *U. S. Dept. Agr. Bull.* 569, 1917.

[3] Howard, B. J., and C. H. Stevenson, *U. S. Dept. Agr. Bull.* 581, 1917.

[4] For a thorough stúdy of these processes the reader is referred to Cruess, W. V., Olive pickling in Mediterranean Countries. *Univ. California Exp. Sta. Circ.* 278, 1924.

[5] Cruess, W. V., How a New Domestic Food Industry Was Established, *Food Ind.*, **1**, 170, 1929.

ripe, it is tender and may not withstand the subsequent treatments satisfactorily.

The olives are picked and transported to the factory where they may be either pickled immediately or stored in brine. Storage in brine has some advantages over direct pickling, because the olives can be kept for a period sufficiently long to allow a single factory to remain in operation the year round if necessary, according to Cruess.

The brine treatment and the spontaneous-fermentation process which ensues produce olives which are firm in texture and less liable to subsequent bacterial action since the sugars and soluble nitrogenous material are largely consumed in the favorable lactic acid fermentation.

The treatment of the olives with brine is quite similar to that of cucumber pickling, described elsewhere (page 523). Wooden barrels and wooden or concrete vats are used for the salting and fermentation. A brine having a concentration of salt from 8 to 10 per cent is satisfactory for this purpose. The fermenting olives are submerged in the brine by the use of wooden heads which are kept below the surface. The brine is stirred at intervals to keep it of uniform concentration as far as possible. During the fermentation process it is essential to skim off any surface films which may develop. The Mycoderma, molds, or wild yeasts, which constitute the film, utilize lactic acid in their normal growth and therefore are undesirable, as lactic acid acts as a preservative.

Olives, whether green or subjected to the brine fermentation outlined above, are processed to accomplish a number of purposes which include darkening of color, dissipation of the natural bitterness, a subsequent treatment with brine, sterilization to eliminate the possibility of any microorganisms causing disease, and, finally, packing.

The olive commonly grown in California for pickling purposes, the Mission, is dark in color, but not black as is desired for the ripe-olive trade. Sodium hydroxide solutions of a concentration between 0.5 and 2.5 per cent are applied to the olives for a sufficient time to allow the hydroxide to penetrate the skin. The olives are then oxygenated by direct exposure to air or by bubbling air through water in which they are submerged for a period of 2 to 4 days. The process is dependent on the oxidation of the tannins which are in the olive, and as the tannins belong to the pyrogallol group, it is believed that the darkening is similar to that of pyrogallic acid in alkali solutions. The flesh of the olives treated by aerated water is lighter in color than those exposed directly to air and is consequently of higher value.

Following the preliminary treatment with lye to intensify the color of the olive, another treatment with lye is given to extract the bitterness from the fruit. A 0.5 to 1 per cent solution of sodium hydroxide is applied to the fruit for a period long enough to penetrate to the pit of the

olive. A uniform penetration of the lye is desired, but the process must be controlled carefully as the lye penetrates more rapidly at the stem end. The bitterness in olives is ascribed to the presence of glucosides and this treatment is given to hydrolyze the glucosides by means of a weak alkali. At the same time it is essential that the strength of the alkali and the time of exposure shall be such that the olive is not bleached.

The fruit is then soaked in fresh water, with frequent changes to remove the remaining alkali, until the use of phenolphthalein as an indicator shows that it has been sufficiently leached out. The temperature at which the leaching is done is important because the growth of bacteria during this period may be injurious to the product. To prevent such action it is advisable to have the temperature below 70 or above 120°F. The higher temperature removes the lye much faster and eliminates the dangers of bacterial troubles at this stage in the process, according to Cruess.

TABLE 110.—PRODUCTION OF OLIVES IN CALIFORNIA*

Year	Short Tons
1922	10,000
1925	14,000
1928	23,900
1930	20,000

* Yearbook of Agriculture, 1932.

TABLE 111.—UNITED STATES IMPORTS

Years	Gallons
1909–1910	4,555,000
1910–1911	3,045,000
1920–1921	4,054,000
1924–1925	5,901,000
1929–1930	8,452,000

* Yearbook of Agriculture, 1932.

The olives are next cured or pickled in brine, beginning with a 2 per cent solution of sodium chloride, which is increased gradually to a 3 per cent concentration. Bacteria may again cause fermentation which is sometimes eliminated by the use of a stronger salt solution.

The finished fruit is graded according to color and size and returned to brine until canned. Any rejected fruit is used for the production of olive oil.

For canning a boiling hot brine of approximately 3 per cent is added and the fruit packed warm, using either glass containers or tin cans. If the latter are used, enamel linings are preferable. The filled tin cans are given a short exhaust at 200 to 212°F. so that the contents of the center of the can reach 185°F. Then they are sterilized at 240°F. for 40 minutes, to eliminate the possibilities of *Cl. botulinum* poisoning by killing any spore-forming types of bacteria which may be present.

Olives may be salt-cured by the following method used in Southern Europe. Fully ripe fruit, large-sized and black, is packed in barrels with salt. The salt and olives are alternated in layers, with about 1 lb. of salt used for each 9 lb. of olives. After the barrels are filled they are headed. Water is drawn from the flesh of the olives by osmotic pressure and a brine forms. During the first month of treatment the barrels are rolled every few days to prevent the olives from sticking together and molding, also to insure a uniform brine exposure. During the second month the rolling is done less frequently and by the end of the second month the olives are comparatively free of their original bitterness.

The increasing popularity of the olive is shown by the figures in Tables 110 and 111.

These figures indicate the 1930 crop of olives to be just double that of 1922.

CHAPTER XVIII

VEGETABLE OILS

The use of vegetable oils for food purposes in the United States has increased to a marked extent in the past 50 years. Doubtless this change has been partly due to the more common use of salads in the American diet, but another important reason is the improvement in technological processes which has enabled the production of high-grade oils that are pure, odorless, and tasteless.

Many of these products have been found suitable for the manufacture of mayonnaise, and at the present time the American public exhibits a liking for mayonnaise which requires an annual production estimated by Wesson of some 300,000 barrels of cottonseed oil and about 50,000 barrels of corn and peanut oils.[1]

Refinements in the manufacture of vegetable oils, and the developments in hydrogenation which enables such oils to be solidified, have also caused them to be used in large quantities in place of animal fats as shortening and cooking oils. This practice has become so prevalent that some opinions have been expressed to the effect that lard will eventually become an unknown food material unless the packing industry reacts to the situation.

Vegetable oils and fats are also important constituents of margarines, or butter substitutes, which have attained in recent years as high an annual production as 370 million pounds (1929).[2]

In addition to the above-mentioned products, vegetable oils have a wide usage in the manufacture of soap which has formerly been to a considerable extent a by-product industry of the packing house. Now we see also the interesting spectacle of the soap companies engaging in the manufacture of cooking oils and shortening materials.

COTTONSEED OIL

Cottonseed oil is a semidrying oil obtained from the seeds of numerous varieties and species of the plant *Gossypium*, of the order Malvaceae. Sixty years ago these seeds were of little value and were either used as fertilizer or thrown away. In the latter part of the last century it was found that, by heating and pressing, an oil could be extracted which when

[1] Wesson, D., *Food Ind.*, **1**, 212, 1929.

[2] U. S. Department of Commerce, Census of Manufacturers, 1931, 1934.

properly refined, compared favorably with olive oil for food purposes, although with slightly different composition. This oil, which could be recovered to the extent of 25 per cent of the weight of the seeds, was used for some time as a substitute for olive oil until even more important products for which it was well adapted were devised, which demanded its use. At the present time the annual world production of cottonseed oil is estimated to be over 4 billion pounds, and an unimportant by-product has assumed a position of considerable importance in the food industry.

In the United States the production of cottonseed oil is confined to the great cotton belt, extending from southern Virginia along the Atlantic coast, and southwest to Texas and Oklahoma. Although cotton has also been cultivated in the warmer parts of California, Arizona, and New Mexico, particularly in irrigated valleys, the production of cottonseed oil has not become important in these restricted areas.

The cottonseed-oil industry is now the largest edible-oil industry in this country, with a production of 1,310,000,000 pounds of crude cottonseed oil in 1920. In 1928 this production was increased to 1,604,000,000 pounds, an increase of over 20 per cent.

TABLE 112.—COTTONSEED AND COTTONSEED PRODUCTS IN THE UNITED STATES*
(1,000 short tons)

Year beginning July	Cottonseed		Cottonseed products	
	Production	Quantity crushed	Crude oil	Cake and meal
1919–1920	5,074	4,013	606	1,817
1920–1921	5,971	4,069	655	1,786
1921–1922	3,531	3,008	465	1,355
1922–1923	4,336	3,242	501	1,487
1923–1924	4,502	3,308	490	1,518
1924–1925	6,051	4,605	702	2,126
1925–1926	7,150	5,558	809	2,597
1926–1927	7,982	6,306	944	2,840
1927–1928	5,759	4,654	738	2,093
1928–1929	6,435	5,061	802	2,282
1929–1930	6,590	5,016	786	2,232
1930–1931	6,190	4,715	721	2,165
1931–1932	7,602	5,328	847	2,402
1932–1933	5,783	4,621	723	2,093
1933–1934	5,804	4,157	652	1,889
1934–1935	4,324	.....	...	.....

* Yearbook of Agriculture, 1935.

The United States is the leading exporter of cottonseed oil, with the United Kingdom, Egypt, Peru, China, and Brazil as other exporters.

The principal importing countries are Canada, Netherlands, Germany, France, Norway, Denmark, Belgium, Argentina, and Sweden. Our exports of cottonseed oil in 1929 amounted to over 29 million pounds, of which Canada received over 20 million pounds. The three next importers of this oil were Mexico, Cuba, and Argentina.

TABLE 113.—INTERNATIONAL TRADE IN COTTONSEED OIL*
(1,000 lb.)

Country	Average 1925–1929		1930		1931		1932		1933	
	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports
Principal exporting countries:										
United States	49,815		28,297	0	22,578		55,767		35,435	0
United Kingdom	46,146	18,657	38,835	35,564	33,378	13,803	38,078	13,581	21,007	16,968
Egypt	22,724	80	24,717		17,637		18,885		4,414	38
Peru	9,526		6,947		1,923		911		876	0
Principal importing countries:										
Canada	0	39,439	0	26,071	0	17,205	0	54,834	0	30,358
Germany	283	19,296	1,472	12,293	277	9,216	75	10,040	79	6,942
Netherlands	6,481	16,831	119	810	51	4,323	45	1,810	271	5,144
France	34	7,792	57	8,103	7	6,789	1	5,223	27	4,255
Denmark	809	6,624	786	4,[illegible]	484	5,919	517	3,104	618	1,150
Norway	0	4,474	0	1,363	0	582	0	1,655	0	592

* Yearbook of Agriculture, 1935.

Treatment of Cottonseed.—The storage of cottonseed presents an important problem because large quantities must be stored at certain periods of the year before it can be processed. The amount of moisture present has a great influence on the degree of deterioration which occurs, and if the moisture content is higher than approximately 10 per cent, there is a possibility of damage by heating, sometimes even to the extent of spontaneous combustion.

Proper care in handling the seed is essential because any excessive moisture or spontaneous heating will tend to lower the yield of oil, and at the same time lower the value and quality of the press cake which is commonly used for feeds.

The seed should be stored in dry, well-ventilated structures, usually built of steel or concrete, although sometimes silos are used for this purpose. In the handling of seed on a large scale it is necessary to avoid the hazards of dust explosions by protection against sparks from electrical equipment and static electricity as far as possible.

Cottonseed varies in chemical composition according to variety, climate, soil, and other factors. The American crop has an average oil

content of approximately 19 per cent which is slightly higher than the average for Indian cottonseed. The production of oil per ton of seed also varies to a considerable extent, although with American methods it is around 300 lb. per ton.

The actual manufacture of oil from the cottonseed is preceded by cleaning the seeds by the use of revolving screens, cyclone cleaners, and electromagnets which take out foreign substances of a mètallic nature. To carry out these operations efficiently a moisture content in the seeds from 8 to 11 per cent is said to be necessary. Preliminary humidification is usually necessary to obtain this amount of moisture because, as was stated above, such large water contents would be undesirable during storage. The next operation is accomplished by delinters which remove the short cotton fibers adhering to the hulls. If the oil is to be obtained by pressing the meats (kernels or decorticated seeds), the seeds go from the delinters to hullers which crack the seeds, and subsequently the hulls and decorticated seeds are separated by successive screenings.

Two general methods are available for the removal of the oil from the seed or from the decorticated seed which is more commonly used. The first method, using an expeller, requires grinding and drying the meal, thereby obtaining a low moisture content (2 per cent or less) previous to extraction. The second method, hydraulic milling, includes passing the seed or the meats through oil-seed rolls, heating or cooking the meal to a temperature slightly above the boiling point, and finally the formation of press cakes of the hot meal in press cloths which are subjected to a pressure of as high as 2 tons per square inch in an hydraulic press.

The crude oil obtained is then generally filtered in a filter press to remove any suspended impurities, although it is sometimes run into settling tanks so that the press foots (*i.e.*, finely divided solids from the seed) will have settled previous to filtration.

Edible oil is obtained by refining the crude cottonseed oil. This is done by a process using caustic soda, followed by bleaching and deodorizing. The bleaching is carried out by the use of Fuller's earth, sometimes aided by activated char. For deodorization the general principle of heating and distillation under reduced pressure is used to distill off the undesirable impurities causing odors. The edible oil is bland, almost odorless, and of agreeable taste. If well refined, it has good keeping quality, but on long storage in contact with air a slight rancidity may develop.

COCONUT OIL

A large part of the coconut oil used for food purposes is produced in the Philippines, although the Netherlands, France, Ceylon, British Malaya, Dutch East Indies, and Germany are all exporting countries.

The United States is the chief importing country, having in 1927 imported 293,370,000 lb. of oil. The United Kingdom, Belgium, and Denmark follow as the major importing lands, with Sweden, Egypt, Italy, British India, and New Zealand ranking lower in importance.

Table 114 shows (in 1,000 lb.) the principal international trade in coconut oil for 1925 and 1927.

TABLE 114

Country	1925		1927	
	Imports	Exports	Imports	Exports
Principal exporting countries:				
Philippine Islands	0	229,560	0	319,232
Netherlands	11,460	115,689	12,147	115,792
France	12,566	23,498	9,606	32,012
Ceylon	18	69,095	11	75,393
Principal importing countries:				
United States	233,174	17,901	293,370	20,418
United Kingdom	68,723	5,914	91,349	5,535
Belgium	25,533	6,196	39,343	3,627
Denmark	38,321	10,836	19,126	22,132

The export trade in products of the coconut is the largest business in the Philippines; for example, in 1928, $47,542,940 was realized from the sugar crop, while coconut oil brought in $23,489,173, copra $22,542,341, and desiccated coconuts $3,723,586, or the coconut crop as a whole netted $49,755,100, and was the most valuable crop in the Islands.

The coconut grows on the coco palm. There are still many coconuts growing wild upon the shores of tropical countries, but a large part of the present crop is cultivated in tropical regions where there are suitable soil and abundant moisture. The trees start bearing when five or six years old and produce constantly for many years. The nuts are either shaken or fall off, and are then split open with a machete, axe, or some other mechanical means. The split nuts are then partially dried, and the meats removed from the shell for further drying. Sun drying is the principal method used. Sometimes the drying is hastened by burning the oil of the coconut shells beneath the rack on which the meats are exposed. Such drying is known as smoke drying. In recent years artificial dehydration of the meat has been applied to a limited extent. This is the best but also the most expensive method. Sun drying is a rather uncertain and inexact process and fungi of various kinds and the action of the intense sunlight may decompose and destroy large quantities of the oil. The dried meats finally obtained make up a hard, brownish, shell-like product commercially known as copra.

Formerly very little oil, as such, was shipped from the producing regions. Since the native growers lacked the skill and the expensive machinery for extracting the oil, they generally sold their crop in the form of copra. Now, however, efficient plants have been established to extract the oil in the producing regions, and the oil is transported to America or Europe in bulk, often in tank ships. Since coconut oil is a solid at ordinary temperatures, the (tank) ships are supplied with steam-heating coils which heat the oil to above 70°F. whenever it is necessary to empty the tanks. Many of the tank boats used in the trade carry loads of petroleum to the Philippines on the way out, thus utilizing the facilities of the vessel in both directions. (Obviously the tank must be thoroughly cleaned before the coconut oil is pumped on board.)

In the manufacture of oil, the copra is carried along a moving belt where foreign matters and refuse are removed from it, and then it is carried through machines where it is shredded. The shredded copra is next heated by means of steam to soften the tissues and liquefy the oil, and is then pressed. The first pressing removes much of the oil. The compressed cake is ground and again pressed. The remaining material is high in protein and is sold as cattle feed. The yield of coconut oil averages about 36 per cent by weight, based on the undehydrated coconut meat.

Purification or refining consists in removing the free fatty acids by means of saponification with sodium hydroxide or sodium carbonate; passage of the oil through coarse, heated bone meal to clarify it; and then filtration.

Of the many uses, coconut oil probably finds its principal outlet in the manufacture of soaps, shaving creams, and cosmetics. It also has a large use in oleomargarine (and hydrogenated oil products). A butter substitute made up of coconut and peanut oils was first developed in France and has had considerable popularity elsewhere.

The estimated per capita consumption of edible coconut oil in the United States for 1931 was 4.73 lb., which is about one-half the apparent consumption of edible cottonseed oil during that period, namely, 10.6 lb., and five times that of corn oil, 0.85 lb. per capita.[1] The food uses of coconut increased to a considerable extent between 1920 and 1930 according to consumption reports.

OLIVE OIL

The olive tree grows in semiarid mild or subtropical regions, in both hemispheres. The world's foremost center for olive raising is Italy, but it is practiced throughout the so-called "Cradle of Humanity," or the parts of Europe, Asia, and Africa bordering upon, or near to, the Mediterranean Sea. The olive also grows well in South Africa, Australia,

[1] Supplement to *U. S. Dept. Comm. Bull.* 38, Domestic Commerce Series.

China, Peru, Chile, and Mexico. In the United States, the main region is in the southern part of California, although it is also produced in the Southeastern and Gulf states. Italy, Spain, and France are the world's main producers, and exports of olive oil to the United States from these countries for the year ending June 30, 1929, were as follows:

Country	In 1,000 Lb.
Italy	62,202
Spain	16,910
France	6,182
All Europe	86,821
Total imports to United States	88,118

These figures indicate that over two-thirds of our olive oil is imported from Italy.

In the region about the Mediterranean, olive oil has served as the principal source of fat in the diet for thousands of years. Land for the raising of cattle which could produce an alternative for olive oil in the form of butter fat is more limited than in our country, as is also the pasture forage during the hot, dry summers. Here olives are raised mostly for their oil and but little for pickling purposes. In southern California, on the other hand, olives are grown for pickling purposes rather than oil.

The olive tree grows slowly and to great age and may attain large diameter, although in cultivation the tree rarely grows to a height of more than 30 ft. A calcareous soil is best adapted for raising olive trees, although light soils and even well-drained clay will permit growth. The quantity of oil produced from olives is primarily dependent on the soil and climate, as well as on the variety of tree. It is seldom that more than 25 per cent of oil is obtained from our native American olives, while in Italy it is not uncommon to procure as high as 50 to 60 per cent, based on weight of the fruit.

In olives the glycerides of the unsaturated acids are present in greater quantity than are those of the saturated fatty acids. Olive oil is a non-drying oil and should not be exposed to extremes of light and temperature. Light fades its color, heat makes it rancid, and cold will cause it to congeal and separate.

Olives are best for oil purposes when picked at full maturity. Over-ripeness means a larger percentage of stearin and palmitin, fats which solidify at low temperatures and which cause cloudiness in the olive oil, especially in cold weather. Underripe fruit does not produce so much oil and the flavor is more likely to lack the desirable quality. Bruising does not seriously injure the olives for oil making, if the fruit is soon used, but it aggravates the problem of storage, for it is rarely possible to use the olives just as quickly as they are gathered. Only the sounder olives are

TABLE 115.—OLIVE OIL: INTERNATIONAL TRADE*
(1,000 lb.)

Country	Average 1925–1929		1930		1931		1932	
	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports
Principal exporting countries:								
Spain	164,975	2	235,678	0	206,921	0	138,805	0
Italy	66,494	,769	159,698	132,561	129,470	180 581	99,761	83,518
Tunis	53,947	458	109,301	151	28,910	713	52,792	814
Greece	28,559	123	18,514	7	21,614	5	68,113	0
Algeria	28,466	115	54,152	79	18,309	49	40,282	87
Turkey	18,185	198	10,452	4	40,254	35	5,459	0
Serbia and Lebanon	4,283	339	6,397	413	7,199	351	7,258	256
Morocco	4,206	282	3	1,361	0	2,762	0	1,729
Yugoslavia	1,077	861	322	542	182	402	136	184
Principal importing countries:								
United States	0	847	0	162,860	0	119,363	0	131,942
Argentina	0	334	0	130,715	0	91,782	0	79,956
France	13,958	146	25,446	72,390	22,389	46,792	20,238	55,635
United Kingdom	324	100	269	21,179	208	19,604	390	24,344
Cuba	0	654	0	20,983	0	14,490	0	17,643
Chile	0	103	0	6,741	21	5,288	4	1,758
Uruguay	0	410	0	18,753	0	15,115	0	10,632
Brazil	0	808	0	18,399	0	5,848	0	11,595
Norway	0	098	0	5,882	0	2,960	0	8,500
Portugal	5,722	659	8,020	26,510	3,979	7,005	8,671	3,271

* Yearbook of Agriculture, 1935.

selected for storing, since the bruised ones are more liable to mold and to bacterial fermentations, and it is difficult to eliminate the moldy flavor when it is once established. Storing before use is done in several ways in different sections. One method is to heap up the fruit in deep piles on the ground. This is an undesirable procedure, for the fruit sweats; it becomes somewhat dehydrated and bacterial fermentation ensues. The odors and flavors which develop resemble those of ensilage, and it is almost impossible to eliminate them. A better method is to spread the olives in thin layers on wooden trays, as air circulation prevents mold growth and greatly retards fermentative action, but this method is too expensive to employ on a large scale. Sometimes (in Spain) salt is sprinkled over the olives to inhibit mold growth and to limit bacterial action. In California, the olives are preserved in brine.

After the olives are washed to remove dirt and leaves, the oil is obtained by a series of crushings and pressings. The best oil results from the first pressing, using pressures of 400 to 500 lb. per square in., and is called "virgin" oil. The second pressing gives a second-grade edible oil, and the pressure used may be as much as 1,500 lb. per square inch. The

remaining pulp is mixed with hot water, recrushed, and again pressed. Much of the oil thus obtained comes from the seeds of the olives and is considered to be inferior in quality, for it contains an enzyme which speeds up the degeneration of the oil and produces more solid fats. This oil serves for technical rather than food purposes. These press residues may be ground up with hot water and run into settling tanks, and the remaining oil then skimmed off from the top of the tank. The lowest grade of olive oil, known as sulphur olive oil, is procured by the extraction of the fat from the residue with carbon disulphide, CS_2.

Oil is separated from the juice by means of settling. Bitterness in olive oil, a natural condition in the fresh oil, is removed by washing the oil in water, since water seems to dissolve the bitter material. To get rid of the pulp and emulsified water still remaining in the oil, the liquor is run into settling tanks for a number of days, where in addition some of the solid fats separate out. Mixing with infusorial earth and filtering through canvas bags produce a fairly pure oil. The oil now has to be aged, and this end is accomplished through storage in tanks of galvanized iron, tin, or glass-lined concrete, or earthenware receptacles. A final filtration of the oil through filter papers completes the process of refining and purification.

If the oil is too highly colored, it may be reduced by the aid of bone black or Fuller's earth.

Free acid is separated from the oils by treatment with alkalies, and the employment of either bone black with heat and a stream of carbon dioxide, CO_2, or ethyl alcohol, or with superheated steam to take away undesirable odors and flavors, is possible.

Besides its extended use in simple form as an article of diet, olive oil is used in the packing of sardines, and as an ingredient in other prepared foods. Other commercial uses are in the manufacture of high-grade soaps.

PEANUT OIL

The peanut is a crop plant of much greater importance than is commonly understood. In 1928, this country produced a crop of 855,096,000 lb. of peanuts from 1,211,000 acres of land. North Carolina produces nearly one-quarter of the peanuts raised in the United States, the crop report showing 215,250,000 lb. as her commercial production for the year ending June 30, 1929. During the same year Georgia raised 189,000,000, Virginia 141,056,000, and Alabama 126,000,000 lb. of peanuts. It would seem that our total was a sufficient amount to meet the public demand in the United States, yet 63,783,000 lb. of shelled peanuts were imported from China, Japan, and other countries in 1928. The peanut grows well in the warmer parts of the temperate zones and these regions produce

the bulk of the world crop. It is said to grow best in the tropics, but its cultivation there has not been highly developed.

The major portion of the crop is now used for the production of peanut oil. The international trade in peanut oil for 1927, and the principal countries concerned are shown in Table 116.

Table 116.—International Trade in Peanut Oil. 1927
(1,000 lb.)

Country	Imports	Exports
China	0	78,889
France	12,728	62,483
Germany	5,861	52,507
Dutch East Indies	1,756	1,823
Netherlands	61,789	34,735
United Kingdom	46,411	9,354
Algeria	23,477	250
Canada	4,811	0
United States	2,847	0

In 1925, 11,927,000 lb. of crude and virgin peanut oil were produced in this country; in 1927, 14,014,000 lb.; and in more recent years the production has been over 15,000,000 lb. annually, while importation has amounted to nearly 5,000,000 lb. at times.

The oil is secured by pressing the crushed seeds with hydraulic presses. In general, peanut oil is milled and refined in a manner similar to cottonseed oil.

CORN OIL

Over 100 million pounds of corn oil are produced annually in the United States from the removed germs of Indian corn (*Zea mays*). The manufacture of oil is a by-product industry associated with the glucose, starch, and other food industries in which corn is employed. Based on weight of the whole corn, a yield of 6 to 10 per cent of oil is obtained. Its principal uses are in cooking and salad oils. It is a semidrying oil.

SESAME OIL

In India and the Indian archipelago the seeds of the sesame plant are used as a source for oil. The plant is also grown in Egypt and other countries bordering the Mediterranean. France prepares large quantities of the oil for food purposes. In some of the European countries its presence in oleomargarine has been obligatory. It has a pleasant taste and no odor, and has served much, as has cottonseed oil, as an adulterant

of olive oil. Commercially, sesame oil is more important than olive oil, although less widely known. Its uses are similar to those of olive oil.

SOYBEAN OIL

The United States produces around 10 million pounds of soybean oil annually and imports over 15 million pounds. The oil is used for industrial and food purposes; under the latter use would come its employment as a butter and lard substitute, as an edible oil, and as a salad oil. Soybean oil is a good and relatively cheap semidrying oil and for that reason three-fourths of all the oil used in this country is absorbed in paint and varnish industries and in the manufacture of linoleum, oil cloth, and artificial leather.

China, Denmark, and Japan are the great exporting countries. It is one of the most important agricultural industries of China, and during the year ending Dec. 31, 1927, China exported 329,298,000 lb. of soybean oil. The United States imported a total of 17,172,000 lb. of soybean oil during the year ending June 30, 1929. Of this amount 11,089,000 lb. came from Kwantung, 1,520,000 lb. from China, and 1,729,000 lb. from Japan.

TABLE 117.—SOYBEAN OIL: INTERNATIONAL TRADE*
(1,000 lb.)

Country	Average 1925–1929		1931		1932		1933	
	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports
Principal exporting countries:								
China	244,894	0	196,119	0	62,205	0	0	0
Germany	45,828	30,004	55,137	20,441	68,424	8,463	70,682	2,743
Denmark	36,742	3,670	40,937	1,764	49,352	4,977	41,285	4,058
Japan	14,393	323	16,009	568	14,115	548	2,965	0
Sweden	12,917	10,182	2,312	24,302	1,6[illegible]	28,645	1,655	15,739
Total	354,774	44,179	310,514	47,075	195,782	42,633	116,587	22,540
Principal importing countries:								
Netherlands	40,024	109,176	24,140	62,175	31,808	56,945	26,130	37,559
United Kingdom	49,942	75,917	32,294	62,265	5,909	61,130	1,380	44,365
United States	4,528	19,545	4,551	4,916	2,647	405	1,569	3,669
France	159	17,401	0	7,337	345	8,672	104	8,506
Morocco	0	9,855	0	9,911	0	16,073	0	7,770
Algeria	19	6,394	0	2	0	1,131	0	96
Austria	17	6,011		6,062	1	6,566	0	20,874
Canada	0	989	0	1,900	0	1,578	0	2,412
Total	94,689	245,288	60,986	154,568	40,710	152,500	29,183	125,251

* Yearbook of Agriculture, 1935.

STORAGE OF OILS

The deterioration of fats and oils is the cause of considerable loss, not only in the raw materials but also in those food products in which they may be incorporated. Fats and oils are glycerol esters of fatty acids, but differ somewhat in the glycerides that they contain and in the amounts and proportions of each. Cottonseed oil contains palmitin, olein, and linolein, together with small quantities of stearin, arachidin, and cholesterol.

Under certain conditions of storage the flavors and tastes of oils may change to a marked degree. Certain of these changes, with the development of undesirable compounds, are characterized as rancidity. While many investigators feel that oleic acid esters are the constituents of oils most susceptible to change, there is much discussion regarding the exact compounds which cause the undesirable odors and tastes.

One theory, held by Powick, is that heptylic aldehyde is the sole cause of such off-flavors. Some German workers cite the particular effect of heptyl and nonyl aldehydes in this respect but suggest the possibility of other aldehydes, ketones, and peroxides playing a part. Others have stressed the importance of peroxides in these changes. It is believed that the chemical changes which occur are largely oxidative and that these take place chiefly in fats which contain unsaturated fatty esters. These oxidative changes give rise to peroxides and other products, with subsequent increases in acidity. As these reactions are primarily oxidations, the presence of oxygen is conducive to their development. The presence of moisture and high temperatures both accelerate such changes. Light (particularly the yellow-orange region, 6,000 to 6,500 angstrom units in the visible) and ultraviolet light have a marked ability to hasten such changes. Certain metals are very active catalysts in the oxidation of fats. Copper is most active, being able to reduce the induction period to less than one-tenth its original value when present in only a fraction of a part per million. Iron, nickel, and cobalt exhibit similar but less marked effects, while manganese and chromium have only a weak effect, and tin and aluminum are without effect.

Microorganisms may bring about deteriorative changes in fats, both oxidative and hydrolytic. The molds, especially Penicillia, have been shown by Stokoe to cause rancidity in coconut oil, with the formation of various ketones.

The above facts concerning deterioration of oils in storage lead to the conclusions that such products should be made from the freshest materials possible and should be brought to the highest degree of purity before storage. They should be stored in suitable containers, preferably free from injurious metals, and protected as much as possible from access to

oxygen, light, and high temperatures. Moisture and impurities such as proteins in oils may serve as food for microorganisms which in turn may produce enzymes also capable of bringing about changes. Since oils and fats are as a rule relatively free from moisture and impurities, microorganisms play but a small part in such changes if the oil is carefully prepared and properly stored.

CONSUMPTION OF OILS

Montgomery,[1] Chief of the Foodstuffs Division, U. S. Department of Commerce, states that there has been an increase in consumption of vegetable oils amounting to nearly 10 lb. per capita during the last 30 years. At the same time the per capita consumption of butter has dropped about 2 lb. per capita. Lard is used no more now than formerly. Montgomery estimated that 34.6 lb. of edible oils and fats were used per capita in 1900, while during the period 1922–1926, the average quantity consumed totaled 44.46 lb. The increased demand for the vegetable oils has been stimulated by the processes for hardening the oils by hydrogenation. Shortening compounds, composed largely of cottonseed oil, and margarine, containing 50 per cent or more of vegetable oils, chief among which are cottonseed and coconut oils, constitute the major portion of the increment of 10 lb. noted above.

Reasons for a greater use of vegetable oils may be said to be due in great part to the changing civilization; new methods of production yielding better products; the popularity of bakery goods; increased education regarding foods and food values; higher standards of living; the custom of the meat cutters in retaining the "trimmings," which were formerly taken by the retail purchaser; and the relatively cheaper cost of vegetable oils.[2]

MAYONNAISE

One of the increasing uses for edible oils is in the manufacture of mayonnaise, salad dressing, and similar products, including sandwich spreads, French dressing, and Russian dressing. With the developing popularity of salads in the American diet the salad accessories cited above have assumed a relative importance.

According to a survey by the U. S. Department of Commerce,[3] mayonnaise, salad dressing, and similar products were produced to the extent of over 29 million gallons in 1934. During recent years (1931–1934) the salad dressing production has averaged more than a 40 per cent yearly

[1] *Food Ind.*, **2**, 511–512, 1930.

[2] See The American Vegetable Shortening Industry, by G. M. WEBER and C. L. ALSBERG. Food Research Institute, 1934. See also the 1936 Review of Vegetable and Competing Oils, U. S. Depart. of Commerce.

[3] BIRGFELD, C. E., *Fruit Prod. J. Am. Vinegar Ind.*, June 1935, p. 307.

increase each year over the preceding one and has exceeded the production of mayonnaise by several million gallons per year. The production of materials of this nature is much higher in the summer, as the warmer months stimulate the use of salads in the diet. New York, California, and Illinois are the largest producing states, followed by New Jersey and Massachusetts.

The following definition of mayonnaise was set by the United States Food and Drug Administration in 1933. Previous to that time, a much higher oil content, 78 per cent, was required.

"Mayonnaise, mayonnaise dressing, mayonnaise salad dressing, is the semisolid emulsion of edible vegetable oil, egg yolk, or whole egg, a vinegar, and/or lemon juice, with one or more of the following: Salt, other seasoning commonly used in its preparation, sugar and/or dextrose. The finished product contains not less than 50 per cent of edible vegetable oil."

Commercial mayonnaise manufacture is of comparatively recent origin, although products of this nature have been made in the home for many decades. The official definition indicates the components which may be incorporated, but the manufacture of the product requires careful supervision for optimum results. An emulsion is not always stable as many home producers have found by experience. The commercial manufacturer must turn out a product which is capable of retaining its desired characteristics, in spite of wide temperature changes and rough handling, both of which tend to cause emulsions to "break" or separate. Mayonnaise is incapable of final sterilization because of its composition and structure, which consists of a suspension of very finely divided oil globules in water.

The egg yolk performs a very important function as it forms a surface film around the individual oil droplets at the interface. The vitellin content of the egg yolk is believed to play a large part in preserving the stability of the emulsion. The yolk also has considerable influence in the blending of flavors resulting from the other components used in mayonnaise. The earlier manufacturers used egg yolks obtained from eggs broken just previous to use, but in large-volume mayonnaise production it is customary to use frozen egg yolks. These frozen yolks are commercially available at any time; they obviate handling of the shells and disposal of the whites which are not commonly used for mayonnaise and offer certain economies as they may be originally purchased, separated and frozen when egg prices are advantageous.

The oil may be of numerous kinds. Highly purified cottonseed oil and corn oil are most commonly used as they offer no objectionable characteristics if properly prepared. Olive oil is sometimes used in the home, but its keeping qualities are less satisfactory. Soybean oil has been proposed as it has certain antioxidant properties which are desirable. It has

not attained usage in any volume to date, however, because of certain characteristic flavors it develops.

Vinegar is an important constituent of mayonnaise, acting both as a flavoring agent and as a preservative or inhibitor of bacterial growth, if present in sufficient concentration. Cider vinegar or distilled vinegar may be used. The main constituent of both is acetic acid, but the fine flavors which they convey are usually due to esters developed during the fermentation process by bacteria. Cider vinegar is preferred by some, but not all, manufacturers.

The acidity of the product is usually less than 1 per cent, which is not enough to preserve the product except when the most strict sanitary conditions have been used for manufacture, and high-quality clean ingredients are used. Lactic acid has been suggested as an ingredient of mayonnaise and similar products, as its taste is not objectionable, but it cannot be used in accordance with the Federal definition of mayonnaise. It has much better preservative ability than vinegar, however.

The sugar ordinarily used is sucrose, which may be derived equally well from cane or beets as chemically they are identical. The sugar is incorporated in mayonnaise primarily as a flavoring material and may be used in the crystal or pulverized form. Salt is used for the same general purpose. Both sugar and salt should be of the highest quality obtainable. Among the more important spices ordinarily used are mustard and pepper.

The final product to be made from these various components must be a dispersion of oil in a continuous water phase. Opinions vary as to the best procedure from the standpoint of the mixing of the ingredients to obtain the final results. Probably the most common method is that of combining the egg yolk with the spices, salt and sugar in a mixer, to which a small amount of the total vinegar is added. This mixture is then stirred and shortly thereafter the oil is poured in very slowly while the stirring continues. When all the oil has been introduced and emulsified, the remaining vinegar or water is added and stirred into the mass.

Many factors are concerned in the formation of this emulsion, the temperature of the ingredients, the initial proportions of the various materials, the rate of addition, the emulsifying quality of the egg yolk, etc. Gray and his coworkers recommended the use of one-third of the vinegar or liquid at the start.[1]

The consistency of the products varies exceedingly, depending upon the procedures used, and microscopic examination of the emulsion shows great diversity in oil-droplet sizes. Many mayonnaise packers utilize viscolizers or homogenizers to assure the proper dispersion of oil for optimum physical composition, and fill the containers immediately after the product is discharged from the former equipment.

[1] Gray, D. M., C. A. Southevick, and C. E. Maier, *The Glass Packer*, **2**, 397, 1929.

Mayonnaise is subject to two serious types of deterioration, one due to chemical oxidations and the development of rancid flavors and odors, the other resulting from the action of microorganisms. Both of these are closely related with raw-material quality and strict sanitation in the factory. The oils used should be of the highest quality obtainable, and care must be taken to keep oxidative action in the supply at a minimum. The containers are filled very close to the top to leave as little free air as possible above the surface. Vacuum packs are not used, however, as some air is incorporated during the mixing process which would be removed by the vacuum and alter the consistency of the product.

No food-manufacturing factories require more rigid sanitary supervision than mayonnaise plants. All raw materials must be scrutinized. The eggs may be sources of heavy bacterial contamination unless they are carefully and individually broken and of the best sanitary quality. If frozen yolks in large cans are employed, they must be thawed before use, and, unless this operation is carefully controlled and the eggs used immediately, they are subject to changes in taste or even possible putrefaction. Frozen yolks which have been packed with cane sugar, invert sugar, salt, or other compounds may inhibit putrefactive change or present other physical advantages. The equipment used must be clean and sterile and the final containers, which are usually of glass, should be previously well washed and rinsed with pure water. The covers should be protected against contamination with molds or other spoilage organisms. All through such a plant thorough cleaning at regular intervals, at least once a day, is advisable. Alkali is needed to remove oil and

TABLE 118.—ANALYSES OF MAYONNAISE*
(Per cent)

Solids	Ash	Protein	Undetermined, by difference	Fat, total	Salt	Acidity	Total P_2O_5	Egg yolk estimated from total P_2O_5	Oil, estimated
85.96	1.34	1.88	2.04	80.70	1.02	0.40	0.125	8.9	77.7
84.69	1.44	1.13	2.41	79.91	1.33	0.29	0.044	3.1	78.7
90.96	1.04	1.00	2.85	86.07	0.87	0.29	0.062	4.4	84.6
83.45	2.04	1.38	3.79	76.24	1.71	0.40	0.116	8.3	73.5
85.60	1.04	1.88	0.69	81.99	0.89	0.40	0.120	8.6	79.1
84.60	1.29	1.25	1.21	80.85	1.14	0.44	0.091	6.5	78.7
86.07	1.29	1.44	2.85	80.49	1.12	0.31	0.101	7.2	78.1
76.17	1.69	2.75	2.66	69.07	1.14	0.75	0.212	15.1	64.1
80.41	1.99	1.63	4.24	72.55	1.64	0.50	1.105	7.5	70.1
78.44	1.73	2.50	2.90	71.31	1.32	0.75	0.164	11.7	67.4

* From *Connecticut Agr. Exp. Sta. Rept.*, New Haven, 1931. State of Connecticut Pub. Document 24.

grease from equipment, as such cleaning compounds may accelerate fat oxidations. Carelessness in cleaning will leave oil in the equipment which may undergo change and accelerate rancidity in later batches of good oil. Thin films are particularly bad as they present large surface areas to oxygen contact. Any lack of sanitary precaution will create breeding grounds for bacteria and other spoilage microorganisms.

Storage at low temperatures tends to increase the shelf life of mayonnaise, but after a few months, especially in warm climates, it is likely to deteriorate. Many manufacturers make replacements at intervals.

Salad dressings and "whips" are related products, but the latter are often subjected to heat treatment and have higher acid content, which favor preservation and keeping quality. They are therefore less likely to cause trouble in manufacture.

CHAPTER XIX

FRUIT JUICES

Fruit juices of various sorts have been prepared for the food-specialty trade for many years, but recent years have seen great advances both in the numbers of these refreshing beverages and their attractiveness and quality. Lime juice from the tropical islands has long been sold by dealers in high-grade food specialties, while grape juice, both red and white, followed thereafter. More recently bottled or canned juices, such as apple juice or fruit cider, cherry juice, pineapple juice, cranberry juice, prune juice, tomato juice, and sauerkraut juice have been produced in large quantities. A great impetus has taken place in the production and marketing of citrus-fruit juices including those from oranges, lemons, and grapefruit. Some of these are also called fruit cocktails, especially if mixed with other ingredients.

The popularity of these types of product is doubtless due largely to their delectable flavors, and perhaps, in part also, to the emphasis which has been given to vitamins in the past decade, as many fruits contain vitamin C. The older products were usually glass-packed, but with the development of more acid-resistant can-lining enamels many products may now be procured in either glass or tin. Much emphasis has been placed on quality in these products; thus it has enhanced their popularity among consumers, and greatly increased their consumption in recent years.

Foremost in the preparation of a palatable fruit juice is the selection of fruit which has an attractive flavor and aroma. Juices produced on a commercial scale must "wear" well, *i.e.*, have good appearance, constancy of appeal, and popularity. Certain kinds of fruit may yield juices that supply a drink which would taste good occasionally, but which would not appeal to the appetite day after day. Besides being of acceptable and tempting taste, the juices must be capable of surviving treatment and storage without loss of those desirable qualities. Experience shows that commercially successful fruit juices must also be tart in flavor or contain a fairly large amount of the natural fruit acids. To secure these qualities the fruits used are picked at a definite carefully regulated time as each fruit has a particular period when the acid and sugar content are at an optimum. Oranges, for example, should be mature when picked, otherwise the juice is bitter, while grapes may be used for juice when slightly underripe.

The fruit used for juices must be absolutely sound and clean. It is impossible to obtain a high-grade juice from an inferior quality of fruit. Rot, moldiness, fermentation, or dirt in crushed fruit spell failure insofar as a high-quality beverage is concerned. Spray residues of a dangerous nature must be completely eliminated from fruits before use. Hence the fruit must be carefully sorted and washed.

Each fruit presents an individual problem in regard to harvesting, crushing, pressing, clarifying, and preserving. In crushing, for instance, the metal of the crusher should be of such a nature that it is not attacked by the fruit acid, thus imparting color and changing flavor. In early attempts to produce citrus juices much trouble resulted from failure to meet this situation. Certain fruits darken or lose their attractive appearance on exposure to air even for short periods of time. All fruit juices are subject to spoilage by microorganisms unless properly handled and stored. The fruit juices discussed below will illustrate some of the difficulties involved.

CIDER

Freshly pressed apple juice or sweet cider is a beverage held in high esteem in many parts of this country, particularly in the Northern and Atlantic states where the apple has been the most characteristic native fruit for generations. The preparation of such a product involves many considerations. The variety of apple used as raw material must be one having an attractive flavor, tartness, sufficient solids to give the juice body, and a reasonable amount of color. Among the varieties which have proved particularly satisfactory in this respect are the Winesap, Northern Spy, Baldwin, and Russet, although many others are used and the juices blended in order to obtain desirable characteristics in the final product.

Although cider is generally made from fruit not capable of being marketed as select fruit and which may be in large part the windfalls and culls, poor and unsound apples will not make high-quality cider. In the larger cider mills where apples are received in truck or carload lots, they are often unloaded into troughs containing running water which is sometimes slightly chlorinated. The water serves to sluice the fruit along to a conveyor, at the same time softening and removing superficial dirt from the surface of the apple. Partially decayed fruit is eliminated by hand picking. As the apples are lifted by the conveyor, they should be further cleaned by water sprays. If the fruit is unusually dirty and a high-grade product is being manufactured, the apples may be passed through a brushing or washing machine in addition. The cleaned apples are next introduced into a grater which reduces the pulp to a fine state of subdivision, or they may in some cases be put through a roller

crusher. The manner in which the apples are ground as well as the state of maturity of the fruit is an important factor in respect to the yield of juice obtained. Too fine a subdivision tends to pack the material so solidly in the subsequent pressing operations that all the juice is not extracted and the same results may occur if the material is not reduced sufficiently in size. Apples having soft pulp are not grated or ground so fine as the more firm varieties.

The ground or grated apple pulp is commonly made into "cheeses" enclosed in special cotton press cloths which are folded over in such a manner that each cheese makes a separate unit and is separated from the one above and below by a rack made of durable wooden slats. The cheeses are made up on a hydraulic press, and when the number of cheeses suffices to reach almost to the top of the press, the pressure is applied from above so that the distance between the top and bottom of the press gradually decreases. In some of the better presses a pressure of many tons may be exerted. The juice is separated from the apple pulp, flows out to the edge of the press, and down to the base where it is collected and runs by gravity to tanks. The remaining pulp which is now called pomace still contains small quantities of juice and, after removal from the press cloth, may be broken up and pressed again. Juice obtained in the second pressing should not be considered first-class cider, however. In some instances the pomace is moistened with water before the second pressing and the juice obtained therefrom is used for the manufacture of vinegar.

Freshly pressed apple juice is slightly cloudy in appearance rather than brilliantly clear. Cider from the press may be marketed directly, although it is more customary first to subject it to a filtering process. The filtration may be accomplished by the use of cloth filters, paper-pulp filters, press filters and some filter agent, such as diatomaceous earth, or clean sand, if a very clear product is desired. If the juice is heated to a temperature of approximately 165°F. previous to filtration, the soluble proteins are coagulated and the subsequent clarification is facilitated.

With the recent creation of markets for bottled cider which may be held for a considerable period before use, refinements in the clarification of the juice have been developed. One of the methods advocated for this purpose has been the combined utilization of gelatin and tannin for the precipitation of suspended colloidal material, followed by filtration. Enzyme preparations, capable of attacking pectins and starches which are likely to cause a haze in the juice, have also been found useful in this respect.[1]

[1] KERTESZ, Z. I., *New York State Agr. Exp. Sta. Circ.* 124, 1931.

As apple juice normally contains both bacteria and yeast cells which may bring about fermentations unless they are inactivated, it is necessary to pasteurize the product or to add some preservative if it is to be kept for any length of time. Sodium benzoate is the most common preservative utilized to inhibit the growth of yeasts and molds but does not always prevent the development of acetic or lactic acid bacteria. Concentrations of 0.15 per cent of sodium benzoate are usually sufficient.[1] The use of heat treatment rather than preservatives is more desirable from some standpoints but requires careful application in order to prevent undesirable cooked flavors in the product. Flash or rapid pasteurization has been found suitable for this purpose in some instances, using temperatures of approximately 180°F. for very short periods of time (20 seconds), followed by filtration with Super-Cel.[2,3]

When cider is to be preserved in bottles, the heat treatment is sometimes carried out after the juice is sealed in the containers, otherwise it is necessary to have the bottles and the caps sterilized previous to filling in order to prevent infection from these sources and the possibilities of fermentation and cloudiness.

Some bottled ciders are carbonated, according to current practice. The carbon dioxide gas gives additional zest and especially improves the flavor of the cider from some varieties of apples.

Cider may also be canned, in which case it is desirable to have a preliminary heat treatment to expel oxygen, and thereby minimize subsequent perforation of the tin plate. Temperatures of 185°F., or sometimes lower in acid juice, may be sufficient to preserve the product satisfactorily.

GRAPE JUICE

Grape juice has been a popular beverage for many years. In the Eastern section of the country the Concord grape, a strain of the Labrusca variety, is most widely used for this purpose. In the Pacific states the blending of juice from two or more varieties is sometimes practiced in order to combine the fine flavor of the one with the desirable color of the other. The Muscats of that region are generally used to provide the flavor. The most important grape-juice-packing regions are in the states bordering on the Great Lakes, of which New York is first in importance.

The proper manufacture of grape juice starts in the vineyards because the maturity of the fruit has much to do with the flavor of the finished

[1] Cruess, W. V., Commercial Fruit and Vegetable Products, 1924.

[2] Carpenter, D. C., C. S. Pederson, and W. F. Walsh, *Ind. Eng. Chem.*, **24**, 1218, 1932.

[3] Carpenter, D. C., and W. F. Walsh, *New York State Agr. Exp. Sta. Tech. Bull.* 202, 1932.

product. Concord grapes make the best juice when fully mature, although some other varieties should be picked somewhat earlier. All grapes are subject to rapid deterioration after gathering and should be processed as soon as possible to prevent the development of microorganisms and their biochemical effects.

In the usual procedure the grapes are first carefully washed or subjected to a water spray, then crushed and stemmed mechanically. The crushing is accomplished by means of opposing rotating cylinders having corrugated surfaces. The exact treatment depends on the type of grapes being pressed and whether the juice is to be red or white.

In the manufacture of red grape juice the skins must be heated to extract the anthocyanin pigments, which give the red color, while this treatment is not necessary for white grapes. Use of white grapes makes it possible to eliminate the earlier stemming operation when white grapes are used because if the crushed product is not heated, the stems are not injurious.

After the heat treatment to temperatures slightly above pasteurization, the crushed grapes are pressed in the same general manner used for apples. Low yields result if the heating process is omitted.

After the pressing operations have been completed, the juice is filtered and pasteurized. It is then stored at low temperatures to facilitate the precipitation of coagulated proteins and enable the separation of argols, the source of cream of tartar, a normal constituent of grape juice. Storage temperatures close to the freezing point are most satisfactory. Glass-lined containers are best adapted for such storage, but regardless of the type of container, it should be sealed to prevent infection of the pasteurized juice during this period. If much lower or freezing temperatures are used, only a few hours are needed to bring about the separation of cream of tartar and by thawing the juice this deposit may be readily filtered out.

Ordinary filtration will not readily remove completely the turbidity of grape juice, but this may be accomplished by adding organic materials such as casein, or through the use of enzyme concentrates derived from molds.[1] Either of these treatments, followed by filtration, will produce a relatively clear product.[2]

The clarified juice is again heat-treated at a temperature of 170°F. or more for 30 minutes and filled into the final container which should be sterile. As an alternative process this heat treatment may be carried out in the final container. If the grape juice is to be carbonated, this will enable the use of lower pasteurization temperatures. Grape juice

[1] Kertesz, Z. I., *New York State Agr. Exp. Sta. Tech. Bull.* 178, 1931.

[2] Green, E. L., and Z. I. Kertesz, *New York State Agr. Exp. Sta. Tech. Bull.* 181, 1931.

in the Eastern states is not usually carbonated, however. It is possible to sterilize grape juice by filtration using germproof filtering materials composed of paper pulp and asbestos in a Seitz filter, according to Carpenter.[1]

(A series of papers on the preparation and preservation of grape juice has recently appeared in the early numbers of *Food Research*, vol. 1, 1936.)

ORANGE JUICE

Fresh orange juice is one of the most popular fruit beverages, and much effort has been given to producing high-grade commercial products of this nature. Valencia oranges have been most commonly used for juice purposes. Other varieties which have been used satisfactorily include Seedlings, Temple, Florida Pineapple, St. Michael, and Mediterranean Sweets. The preparation of a perfect juice has been extremely difficult, as the flavors so highly desired in orange juice are subject to changes in very short periods of time after the juice has been extracted. The natural flavors are likely to give way gradually to stale off-flavors, owing to oxidations and enzyme reactions in the juice, unless special methods are used.

Previous to extracting the juice, the oranges are washed to remove surface dirt and then sorted. The sorting process is important and should be done with extreme care so that all partially decayed or overripe fruit will be discarded as they will not make high-grade juice. Fruit which has been subjected to sweating or coloring is also less desirable than normal fruit. The extraction may be carried out by spindling or by crushing and pressing. If the juice is obtained by crushing, it is more likely to have oil from the skin than when rotating spindles are used on the cut halves. The spindle or burr slowly reams out the inner pulp but has little opportunity to free oil from the peel. Immediately after reaming, the juice and pulp are screened to remove seeds and particles of pulp.

To have satisfactory flavor, it is necessary that the total acidity of the orange juice should be at least 1 per cent according to von Loesecke. He found the addition of sugar sirup also tended to improve the product. The addition of terpeneless orange oil also was found to improve the flavor.[2]

As oxidations tend to impair the quality of the juice by exposure for even brief periods of time, it has been found very helpful to subject the juice immediately to a vacuum which de-aerates the juice. It is

[1] Carpenter, D. C., C. S. Pederson, W. F. Walsh, *Ind. Eng. Chem.*, **24**, 1218, 1932.

[2] von Loesecke, H. W., H. H. Mottern, and G. N. Pulley, *Ind. Eng. Chem.*, **26**, 771, 1934.

necessary to heat the juice if it is to be stored any length of time, and this may be accomplished by means of coil flash-pasteurization equipment. Various temperatures have been used, but most satisfactory results have been reported by von Loesecke at the U. S. Citrus Products Station at Winter Haven, Florida, using temperatures of 205°F. for 5 seconds.[1] The heat treatment used is generally sufficient to prevent subsequent fermentation and to inactivate enzymes. Heat treatment is immediately followed by rapid cooling of the product to 170°–180°F., and the filling of the containers under vacuum.

After the containers, which may be bottles or tins, are sealed, further cooling is carried out to bring the juice as rapidly as possible to storage temperatures. Canned orange juice prepared in a somewhat similar manner will keep well for a number of months. The lower the temperature of storage the longer it will keep without undue changes in flavor. A special citrus enamel lining for such cans has been found to result in retention of better flavors than the use of ordinary tin.[2]

It has been shown that changes which go on in orange juice and cause darkening are also deleterious to the Vitamin C content of orange juice.[3] Conditions which tend to cause these changes should therefore be avoided. The presence of salts of tin and some sulphites retard oxidative changes of this nature. The storage of orange juice packed in glass at low temperatures is advantageous as it tends to slow down darkening which would be rapid in juice at moderate temperatures. Joslyn and Marsh have found that even minute quantities of copper and iron salts, such as would be obtained by use of utensils and machinery of these metals, tend to impair flavors, and that the most satisfactory metals for handling orange juice are aluminum and some of the corrosion-resistant steels. They also recommend precooling the fruit before reaming.

Although a relatively new product, in 1933 there were 111,000 cases of orange juice canned in the United States.

Freezing has also been used as a means of preserving citrus juices. Juice sealed in vacuum and stored in airtight containers at 0°F. is said to keep well. In one process for freezing citrus-fruit juice, the fresh juice passes through brine-chilled coils, thus precooling the liquid to slightly above the freezing point of the juice. It is then discharged into enameled cans and frozen at 0°F. Storage is usually at temperatures close to 0°F. for best results. Unless the product is previously heat-

[1] von Loesecke, H. W., H. H. Mottern, and G. N. Pulley, *Ind. Eng. Chem.*, **26**, 771, 1934.

[2] Joslyn, M. A., and G. L. Marsh, *Food Ind.*, **5**, 172, 1933; *Canning Age*, **14**, 229, 1933.

[3] Joslyn, M. A., and G. L. Marsh, *Ind. Eng. Chem.*, **26**, 857, 1934, and **27**, 186, 1935.

treated, fermentation may be expected if the juice is stored at ordinary temperatures for even short periods of time.

Tremendous interest was taken in refrigerated and frozen orange juice several years ago and some commercial products were developed which seemed satisfactory. However, on long storage undesirable changes were observed which have been obviated in part by the use of vacuum processes, and in others by the use of very low storage temperatures.

The vitamin C content in frozen orange juice does not diminish to any notable extent even on prolonged storage if very low temperatures are used.[1,2]

GRAPEFRUIT JUICE

In the 1933–1934 season over 610,000 cases of grapefruit juice were packed in Florida, while 9,000 gal. of juice were imported from Puerto Rico.

The juice of grapefruit has been canned successfully for a number of years and has attained considerable popularity. As the figures seem to indicate, its consumption has become probably far greater than that of canned orange juice up to the present time (1937). While its flavor is somewhat different from uncooked grapefruit juice, the transition is not so great as from fresh oranges to heat-treated orange juice, and the consumer has readily accepted the flavor of canned grapefruit.

Grapefruit juice contains not only the extracted juice but also some of the pulp of the grapefruit in suspension. In general commercial grapefruit is sweetened by the addition of sugar or sugar sirup.

The canning of grapefruit juice consists of extracting and straining the juice, adding the sweetening, processing, and cooling. According to Stevenson, extraction of the juice must be done in such a manner as to reduce to a minimum the incorporation of the volatile oil found in the yellow peel, as the oil brings out undesirable changes in the flavor of the juice after canning.[3] The grapefruit used must be sound and of good quality. In extracting the juice the fruit is halved and then either reamed, burred, or pressed. Sometimes broken sections of grapefruit from the canning process are used.

Seeds and large pieces of pulp are removed by passing the juice through perforated cylinders or cones of monel metal or stainless steel, provided with internal beaters to break the pulp into small pieces.

[1] NELSON, E. M., and H. H. MOTTERN, *Ind. Eng. Chem.*, **25**, 216, 1933.

[2] BUSKIRK, H. H., W. E. BACON, D. TOURTELLOTTE, and M. S. FINE, *Ind. Eng. Chem.*, **25**, 804, 1933.

[3] STEVENSON, A. E., *Ind. Eng. Chem.*, **26**, 823–825, 1934.

The smaller fragments or cells do not tend to separate readily from the canned juice.

The sweetening of grapefruit juice is accomplished by adding the dry sugar or 65°Brix sirup to such an extent that the final product will have a Brix reading of 14 to 16°.

Processing may be performed in several ways. Whatever the process, the temperature at the center of the can should reach 170°F. and the cans should be cooled immediately after processing. The following are some of the methods in use for processing grapefruit juice:

a. The juice is heated to 160 to 180°F. in tanks, run into cans, the cans are sealed, and then the juice is pasteurized.

b. The juice is run into cans while cold, the cans are exhausted in hot-water tanks or steamboxes, then the cans are sealed, and the juice is pasteurized.

c. The juice is run into cans while cold, the cans sealed in a vacuum-sealing apparatus and then pasteurized.

d. The cold juice may be flash-pasteurized.[1]

A large headspace in cans should be avoided for it favors faster corrosion and undesirable changes in the flavor of the canned juice.

The yield of juice from oranges may amount to 90 to 100 gal. per ton of ripe sound fruit. The juice per ton from lemons is about 60 to 70 gal. while grapefruit yields are somewhat higher.

LEMON JUICE

The canned juice of lemons is also a common product at present. This fruit is also subject to flavor and color changes which require the removal of air as far as possible. The general methods involved in its preparation are similar to those used for orange juice.

Lemon juice may also be dried to a powder form using spray-drying equipment. When this process is used, it is customary to add sugar to the juice previous to drying.

TOMATO JUICE

Another relatively recent product which has acquired high popularity, not merely for its acceptable taste but also because of its vitamin value, is tomato juice. Practically unknown previous to the World War, it has attained wide usage since that period in both homes and public eating places, owing to its flavor and refreshing qualities. About 4 million cases of tomato juice have been annually packed in recent years.

As with raw material for all juices where delicate flavors are of concern, only high-quality tomatoes should be used. Those which are green,

[1] MOTTERN, H. H., H. W. VON LOESECKE, De-aeration and Flash Pasteurization of Orange and Grapefruit Juices, *Fruit Prod. J.*, **12**, 325–326, 1933.

overmature, partially rotted, or even slightly molded, must be rigidly eliminated as off-flavors originating therefrom can easily be detected. Vine-ripened tomatoes are preferable to others. The correct stage of maturity at harvesting time is essential and care in harvesting and transportation to prevent bruising and contamination are helpful in making quality products. Flumes are used in some plants as conveyors to avoid injury due to excessive handling.

After sorting to eliminate those unfit for use in juice, the tomatoes are soaked in cold water to loosen any adhering soil, then conveyed to rotary washers equipped with pressure sprays. The tomatoes are next trimmed, peeled, and cored, subjected to a final inspection, and again washed by sprays.

The next step in the process differs in various plants. In some instances the tomatoes are next scalded by steam and then conveyed to an extractor, or they may be mechanically crushed and then heated before extraction. Any continuous pressure method of extraction can be used, the main consideration being to prevent as completely as possible introduction of air because of its serious effect on vitamin C. Cyclones may be used for extraction, but with this type of equipment it is essential that the tomatoes be first heated, as less oxygen is taken up under these conditions than when cold. The shorter the lapse of time from crushing the fruit to sealing, the better.

In some factories the extraced juice is subjected to homogenization as this tends to shorten the time subsequently required to bring the juice to a boil.[1] This treatment also produces a somewhat more stable suspension of the final product. If any tomato pulp is removed in accomplishing this purpose, the vitamin content of the final product is likely to be lowered, however, according to Kohman.[2] To minimize oxidative changes, it is helpful to vacuumize the tomato juice to remove air, and then handle it under reduced pressure. The juice is usually heated immediately thereafter and filled into glass or tin containers, preferably by use of a vacuum-closing machine. If the product is filled in cans at temperatures of 180°F. or above, further heat treatment is unnecessary if the cans are immediately inverted for a few minutes to heat-sterilize the cover. The filled cans are then cooled.

Flavor and color are of paramount importance in this product. In addition to the use of good raw material and minimizing oxygen contact, the effect of metals on the juice must be considered. Copper may cause poor or astringent flavors. Iron, bronze, brass, and galvanized iron are

[1] Winters, R. H., *Food Ind.*, **2**, 122, 1931; and **4**, 106, 1932.

[2] Kohman, E. F., *Food Ind.*, **3**, 263, 1931; also E. F. Kohman, W. H. Eddy, and C. Z. Gurin, *Ind. Eng. Chem.*, **22**, 10, 1930.

all likely to be deleterious to flavor. Enamel-lined equipment or corrosion-resistant alloys are satisfactory from this standpoint, however.

Pederson and Breed[1] have shown that the spoilage in tomato products is usually caused by nonspore-forming rods or cocci of the genera Lactobacillus or Leuconostoc.[2] Care in preparation and handling of the juice and proper attention to temperature control lessen this type of spoilage as the causative agents are not highly heat-resistant.

CARBONATED BEVERAGES

The production and use of carbonated beverages have increased greatly in recent years. The business has extended from a relatively small, highly seasonal hot-weather industry to one of large proportions. There are over 5,000 establishments in the United States producing carbonated products with an annual value of over 200 million dollars. Some of these products are carbonated natural-fruit beverages such as grape juice and cider. The great bulk, however, is composed of beverages, of which ginger ale is perhaps the outstanding example, containing as a base a flavored sirup which may also be fortified with some fruit acid. Although the food value of these products is not high, they serve a useful function especially in warm weather, and many are pleasant substitutes for hot beverages at the table even in the cooler months.

The following Federal definition for ginger ale indicates the general composition of this type of carbonated beverage.

> Ginger ale is the carbonated beverage prepared from ginger-ale flavor, harmless organic acid, potable water, and a sirup of one or more of the following: Sugar, invert sugar, dextrose; with or without the addition of caramel color.
>
> Ginger-ale flavor is defined as follows: Ginger-ale flavor, ginger-ale concentrate, is the beverage flavor in which ginger is the essential constituent, with or without aromatic and pungent ingredients, citrus oils, fruit juices, and caramel color.

Other carbonated products sometimes have flavors made from flavoring oils and occasionally from synthetic organic derivatives. Sassafras flavor, for instance, is prepared from oil of sassafras and methylsalicylate, oil of wintergreen.

Most carbonated beverages of the ginger-ale type are not heat-treated and therefore would seem to present the possibilities of spoilage by microorganisms. Fortunately, however, carbon dioxide itself when present under pressure tends to inhibit the growth of many types of microbes which would otherwise cause spoilage.

As the presence of such organisms in carbonated beverages is undesirable and the safety of the product from a health standpoint is also

[1] Pederson, C. S., and R. S. Breed, *New York State Agr. Exp. Sta. Bull.* 570, 1929.
[2] Pederson, C. S., *Z. Bact.*, **80**, 42 and 218, 1930.

dependent on the quality of the water supply, much care is taken to insure a pure-water source. In many plants the regular municipal water supply is used, but in some bottling establishments special supplies from privately owned sources such as springs and artesian wells have been provided at great expense. Regardless of the source, the water used should meet the bacteriological and sanitary standards of a high-grade potable water supply.[1] Special filtration is given many waters used for beverages of this sort to remove all possible suspended organic matter as well as microorganisms. Some manufacturing organizations also subject their water supplies to ultraviolet-light exposure to lessen the numbers of microorganisms present.

The water used requires special consideration from a chemical standpoint also, as the lower the total solids content, the better the product. It is undesirable to employ water having over 15 grains of total solids per gallon, and the presence of calcium sulphate (hard water) should be avoided. Distilled water is suitable for use but is not commonly necessary. It is sometimes necessary to have the water supply chemically treated to make it satisfactory for beverage purposes, because the ability of water to take up carbon dioxide gas properly is of great importance. The necessity of having an odorless and tasteless water supply is equally essential and the final treated water must be clear as crystal.

Another main ingredient of carbonated beverages is the sirup. Although present in relatively small quantity in comparison with water, it is the sirup which supplies the flavor and whatever food value the product presents. There are a great variety of sirups, all of which contain sugar and some flavoring material, which may be from natural fruit or more often synthetic flavors. Fruit acids such as citric acid are commonly used as an important constituent of sirups and tend to accentuate the other flavoring ingredients used. The sugar used in these sirups is largely sucrose, although it is now legally possible to use corn sugar without declaration on the label. These sirups are usually subjected to a heat treatment when compounded, but cannot always be depended upon to be sterile. The sugar content of concentrated sirup is usually high enough to restrain growth and to prevent spoilage, even though stored some time before use, but microbes gain entrance if they are not killed by the sugar. Therefore it is essential that the strictest sanitary precautions be taken in making sirups and keeping them chemically and biologically clean during storage. With the elaborate precautions taken to insure water quality, at least equal care should be required in the sirup room.

[1] For such standards see S. C. Prescott and C. E. A. Winslow, Elements of Water Bacteriology, 5th ed., 1931.

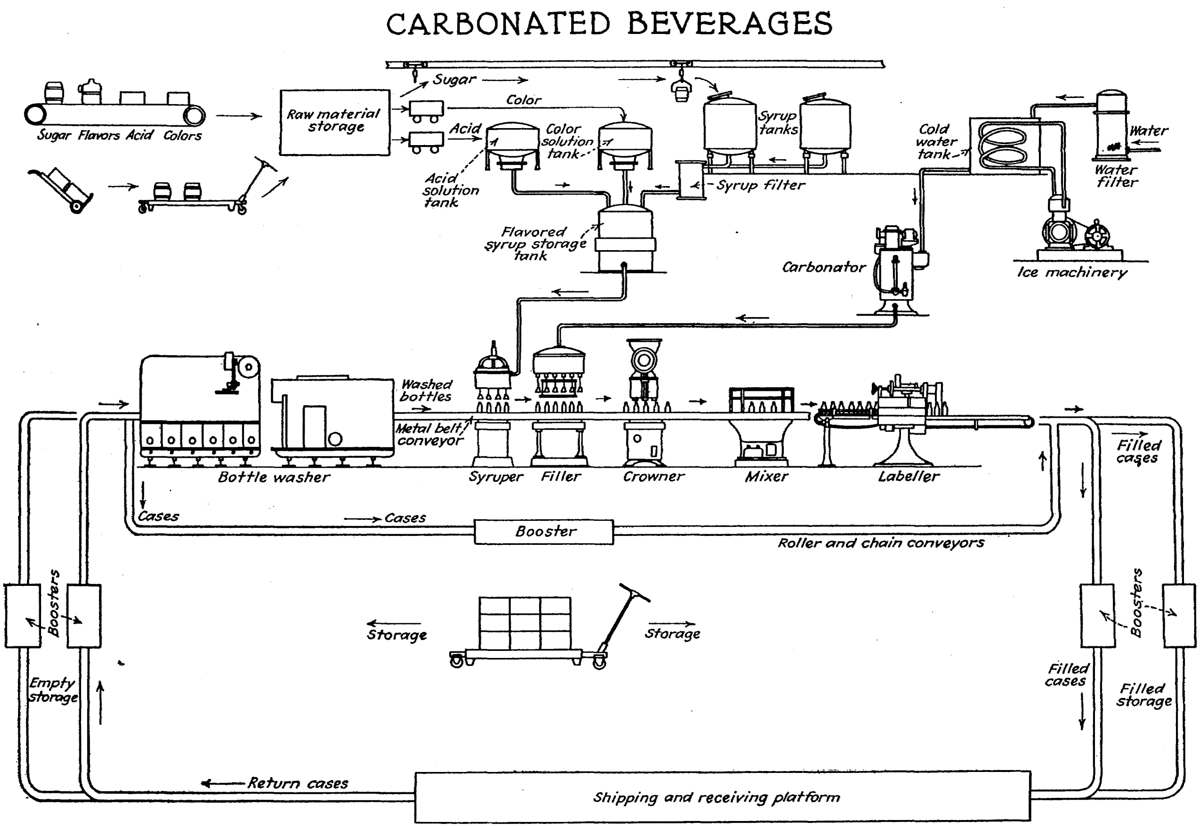

FIG. 64.—Flow chart for carbonated beverages. (*Courtesy of Food Industries.*)

The third ingredient is the carbon dioxide gas. This is usually purchased in cylinders containing the carbon dioxide under high pressure, which facilitates later operations as the pressure is necessary. In order to increase the solubility of carbon dioxide in water, the water in beverage plants is usually cooled close to the freezing point before bottling operations are started. This chilled water is sometimes carbonated previous to the actual filling operations.

The three chief ingredients, sirup, water, and carbon dioxide are ultimately combined in the bottle in definite proportions and in such a manner that the carbon dioxide in the product has a pressure of 3 or 4 atmospheres. The filling operations are carried out in highly automatic machines which cap the bottles after they are filled. The bottles are usually conveyed through a testing tank filled with water which checks the capping operations, as leaks may be detected by bubbles of carbon dioxide rising to the surface.

The bottles used for this industry are generally returnable and thus may be used several times. Therefore another important operation in a beverage plant is the thorough cleaning of all bottles used for the product. Often this equipment is the most expensive apparatus in the plant. The washing process involves the use of hot water, alkaline detergents such as soda ash, phosphates, etc., and mechanical cleaning to insure a sparkling clean practically sterile bottle. Use of alkali solutions of 3.5 per cent concentration and temperatures of 130°F. or more for 5 to 10 minutes will generally suffice in the first step, after which the bottles must be rinsed thoroughly in pure water.

Care is also essential in respect to the treatment of caps. It is of little use to attempt to sterilize water supplies if the contamination by dirt and dust on caps is much greater than that of the original water itself. The caps are not often sterilized before using, but they should be protected from dust and kept as clean as possible. If the cap closure is not perfect, the gas will leak out and the contents become flat. As the carbon dioxide under pressure is the protection against many microorganisms, its loss also makes biological changes of a deleterious nature possible.

Yeasts and related organisms are the principal causes of spoilage in carbonated beverages, as the acidity and sugar content are favorable to their development, although other microorganisms—bacteria or molds—sometimes cause trouble. Most bacteria are inhibited by the acidity of beverages of this sort, while molds are unable to grow when high concentrations of carbon dioxide make up the dissolved gas, and exclude oxygen from the air. Yeasts may cause changes in flavor and produce turbidity and sediment owing to their growth, when such occurs. Cloudiness and even the actual breakdown of the beverages may take place in an infected product, but careful attention to sanitary procedures throughout the

whole train of operations involved minimizes such infection and spoilage. Storage of such bottled products should be at low temperatures and in the absence of sunlight. Carbonated beverages containing certain types of flavoring oils are likely to deteriorate in flavor if exposed to direct sunlight.

Ginger ale is one of the most popular beverages and is produced in two common forms, the so-called "golden ginger ale" and "pale dry" ginger ale. The former usually has a sugar concentration between 8.5 and 9.5 per cent while the sugar content of the latter is slightly lower, ranging from 8 to 9 per cent. The "pale dry" is generally more acid than the "golden" and is equivalent to from 2 to 2½ oz. of 50 per cent citric acid per gallon of sirup, according to Toulouse.

Although it has been shown by Donald and others[1] that carbonation of beverages of this nature tends to lower bacterial counts, particularly on storage, the necessity of using raw materials of high sanitary quality is of primary importance. Careful laboratory supervision of the various processes as well as of the final product is essential to detect any deviation from the desired standards of quality, appearance, taste, and acidity.[2] Clouding, sediment, off-color, and other defects may also be avoided only by regular inspection and examination of the products after storage.

[1] Donald, J. R., C. L. Jones, and A. R. M. MacLean, *Am. J. Pub. Health*, **14**, 122, 1924.

[2] Geer, L. P., *Food Ind.*, **7**, 541, 1935.

See *Educ. Bull.* 4, 1930, of the American Bottlers of Carbonated Beverages: Standards for Beverage Manufacturing Equipment and Recommended Practices.

CHAPTER XX

JELLIES AND JAMS

The manufacture of jellies and jams has become an industry of notable magnitude, the annual value of such products in the United States being about 40 million dollars. Similar products made in homes also mount to a considerable value, as in the rural districts especially where fruits are available at negligible cost, many housewives prepare jelly, jam, and preserves sufficient to meet the needs of winter months for their families.

The fundamental basis of jelly composition is a combination of fruit or fruit juices and sugar. Those fruits which are capable of use for this purpose contain two essential components, pectin and free acid, in sufficient concentrations. Numerous fruits may contain sufficient concentrations of one of these components and may be used if the deficiency of the other is supplemented from another source. This may be accomplished by combination of the original juice with juice from another fruit not having the same deficiency, or by the addition of concentrated pectin or a fruit acid. The flavors which make jellies desirable are often present in the fruit which furnishes the pectin and acid, but some desirable flavors are found in juices that must depend on fortification by the addition of both pectin and acid for proper jelling.

THE PECTIC SUBSTANCES

The jelling ability of fruit juices is primarily dependent on the pectic substances present in some of the plant tissues. These substances may be present in fleshy roots and leaves as well as in fruits.

They occur particularly in the middle lamella of the cell walls and are associated with the cellulose. The pectic substances are complex carbohydrates, and have been found to be comprised of galacturonic acids combined with arabinose and galactose, probably in a ring compound. There are believed to be four molecules of galacturonic acid in the compound, with their carboxyl groups unattached. This complex generally occurs as a methyl ester but may exist as a free acid or metal salt.

The terminology of pectins has been somewhat confused, as the literature has included terms advocated by different investigators in the field. Those terms used subsequently are as advocated by the American Chemical Society.[1]

[1] *J. Am. Chem. Soc.*, **49**, 37, 1927.

When pectic substances are in a water-insoluble unhydrolyzed form as they are found in plant tissues, they are termed protopectins. When the protopectins are subjected to treatment which makes them soluble—which may be accomplished by acid or by enzymes—the resulting soluble substances are termed pectin. The reaction which occurs is possibly an hydrolysis, but opinions on this point are not definite at present.

Pectin therefore is a term designating possibly a group of substances which are water-soluble, and contain the above-named groups, *i.e.*, galacturonic acid, arabinose, and galactose, together with methyl groupings of varying content. If pectin is subjected to further hydrolysis, the methyl ester groupings are diminished and eventually eliminated, leaving ester-free *pectic* acid. Probably there are a number of pectic acids, depending on the extent and type of action utilized in the hydrolysis.

The enzymes which are capable of accomplishing the changes mentioned are protopectinase which acts on protopectin and converts it to pectin; pectase which changes pectin to pectic acid; and pectinase which has the ability to convert pectin and pectic acid to their simplest soluble cleavage products, presumably arabinose, galactose, and galacturonic acid.

Pectin.—Protopectin is not capable of forming a jelly until it has been converted to pectin even though sugar and acid are present. If pectin-containing juice is heated in an acid medium for a prolonged period, the jelling power is likely to be reduced because of the formation of pectic acid. The manufacture of jelly is concerned with getting the juice from fruit with its maximum pectin content, which is usually when the fruit is not quite fully matured but has attained its growth. An equally important factor is the utilization of fruit varieties which are known to contain sufficient pectin for jelly, unless it is desired to add pectin from other sources. Apples and citrus fruits are generally good sources of pectin, although differences in variety and maturity are to be expected. Quinces, pears, plums, and currants are usually good sources, while strawberries and raspberries have lower concentrations.

The normal ripening processes of all fruits and the action of microorganisms tend to lower the pectin content. To prevent or inhibit such losses fruit may be refrigerated, heated, or otherwise treated. Some manufacturers make up their fruit juices, heat them to inactivate enzyme action, and store the concentrated juice at low temperatures from the harvest season until they are able to make the finished jellies, thereby extending the period of manufacturing operations.

Dehydration may also be practiced with pectin-containing materials, such as apple pomace, a by-product from cider presses, which is dried and stored as a base for pectin jells. Drying is likely to affect flavor unless special procedures are available, so pomace pectin is generally utilized in

combination with fruit juices having desirable flavor and color, but deficiencies in pectin. Pomace from the pressing of some varieties of apples, and the white pulp, or albedo, of oranges and lemons are good sources of commercial pectin, which may be extracted and purified in a concentrated form as a thick liquid or as a dried powder.[1,2]

Factors which are desirable in a commercial pectin include high jelling power, or standardized jelling power which enables the use of definite amounts with predictable results, definite setting time which may be fast or slow, depending on its intended use, and absence of definite flavor or odor.

JELLY MAKING

The primary goal in the manufacture of jellies is to obtain a product of uniform and desirable characteristics from the standpoint of color, flavor, firmness, texture, and clearness. All of these characteristics depend somewhat on the fruit as well as on its pectin and acid content and the amount of sugar added.[3] In general, the jelly should be firm enough to retain the shape of the container when removed, and of course to withstand shipping conditions. If pressed slightly out of shape it should be capable of returning to its original shape. When cut, the surfaces should be clean and smooth. Clarity of the highest order is essential in high-quality products. The separation of liquid from the surface, or syneresis, is objectionable.

In the commercial manufacture of jellies if additional pectin is required, it is not added until the heating process is practically completed. With some of the bulk jellies which have both added pectin and acid, the acid may be placed in the final container so that the jelly will not set prematurely.

For jelly making, crab apples, grapes, acid varieties of apples, currants, sour blackberries, lemons, sour oranges, and grapefruit are usually dependable sources of either pectin or acid. Strawberries, rhubarb, and apricots are usually sufficiently acid but may lack pectin, while sweet cherries and quinces may lack acid, yet have abundant pectin.

It has been found that the viscosity of a fruit juice may be used as an index of the jelling power of the juice, and a simple instrument has recently been devised by Baker which is helpful in this respect, because by its use the amount of sugar necessary for success in producing a jelly of desirable physical characteristics may be determined.[4]

[1] Wilson, C. P., *Ind. Eng. Chem.*, **17**, 1065, 1925.

[2] Rooker, W. A., Fruit Pectin, 1928.

[3] Tarr, L. W., *Delaware Agr. Exp. Sta. Bulls.* 133 and 134, 1923.

[4] Myers, P. B., and G. L. Baker, *Delaware Agr. Exp. Sta. Bull.* 149, *Tech.* 8, 1933; Baker, G. L., *Food Ind.*, **6**, 305, 1934, and **7**, 170, 1935.
Baker, G. L., Food Manufacture, December, 1934.

The fruit juices necessary for jelly making are obtained by boiling the fruit with water and later straining or filtering the solid pulp from the juice. The amount of water required depends on the type of fruit. The solid materials such as quinces and apples require more water and longer heat treatment, even though cut up previous to heating, in comparison with berries which need only slight heating and hardly any added water. Some fruits contain sufficient juice capable of extraction to justify two extractions. The duration of heating must be no longer than is absolutely necessary because the flavors may be dissipated or the pectin may be hydrolyzed and converted to pectic acid.

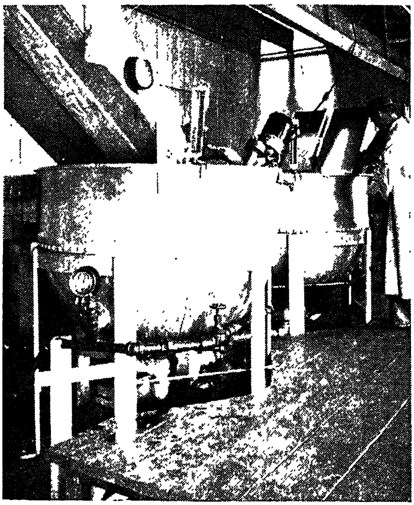

FIG. 65.—Kettles of cranberry jelly. (*Courtesy of Food Industries.*)

The heating is usually carried out in steam-jacketed metal kettles which are sometimes glass- or enamel-lined. Copper is likely to injure the color of fruits if the boiling is prolonged. On completion the hot mass is run into cloth strainers or the more solid raw materials such as apples may be discharged into press cloths and pressed in a manner similar to that used for cider. The pomace may be moistened, broken up, and boiled, or pressed again for higher yields of juice.

Subsequent clearing of the juice is accomplished by numerous devices, including settling tanks, flannel jelly bags, mechanical pressure filters using pulp or kieselguhr as a filter medium, or mechanical centrifuges.

When the hot juice has been filtered, it may go directly to the jelly kettles for immediate jelly making or it may be canned, bottled in large bottles, placed in kegs, barrels, or other large containers, and stored at low temperatures until needed.

When the juice goes to the kettles, sugar is added in amounts predetermined by experience or preferably by laboratory tests, in accordance with the acidity and pectin content of the juice. If the sugar content is too low, the resulting jelly is likely to be tough, while excessive sugar results in a soft, easily broken final product. The hydrogen ion concentration of the mixture is of great importance and for satisfactory results should be approximately pH 3.2 to 3.5. Increased acidity lowers the amount of sugar necessary, but if too acid, "weeping" or syneresis of the resulting jelly is likely to occur. Fruit acids or acid fruit juices may be added if

the acid content is below the optimum amount. Deficiencies in pectin may be encountered, in which case either a juice richer in pectin or a commercial pectin must be added.

The contents of the kettle are boiled for the purpose of concentrating the mixture of juice, pectin, and sugar until the point is reached at which the concentrate will, on cooling, form a jelly of desired characteristics. During the boiling it is necessary to skim off the film or foam of coagulated fruit protein which forms on the top, as otherwise the appearance of the finished jelly would be impaired. Long-continued heating at boiling temperature may cause changes in color or flavor and lower the pectin content. Such changes may be minimized by use of vacuum pans and lower temperatures, in which case it may be desirable to add fruit acids such as citric acid or malic acid to facilitate the inversion of the sucrose.

The point at which the boiling should be stopped is of the utmost importance and may be determined in several ways. The use of an Abbé refractometer enables the determination of the index of refraction which is an accurate means of judgment concerning the end point. Thermometers or thermocouples may be used to indicate the temperature, which should be at approximately the boiling point of a 65 per cent sugar solution, 219 to 221°F. when the process is complete. This determination is of value but should be checked by a sheeting test of the jelly with a spoon. Hydrometers may also be used to determine specific gravity of the material for the same purpose. The maximum jelly strength is usually attained when the sugar concentration of the jelly is approximately 65 to 69 per cent.

When the boiling has been completed, the jellies are run into the final containers while still hot. Glass jars are used for most jellies destined for the retail trade, while cans and pails may be the containers for institutions and the bakery trade. If the small containers are cleaned previous to use, the heat of the boiling jelly is usually sufficient to eliminate any spoilage microorganisms present. The high sugar content inhibits the growth of most microorganisms encountered subsequently with the exception of molds. After the containers are filled, they should be handled as little as possible until the jelly has set because shaking injures the formation of the physical structure.

Small glass containers are usually coated on the top surface with hot paraffin as a seal, or tight metal caps or covers are put on to prevent mold infection. Jellies of lower sugar content may be preserved by subjecting them to a temperature of 180°F. for 30 minutes after sealing. Preservatives were used in early years but are unnecessary in small containers. Bakery jellies of low sugar content packed in pails may have a preservative such as sodium benzoate added, but in such cases its presence must be declared on the container label.

The Federal definitions for jelly are cited below[1]:

Jelly, fruit jelly, is the semisolid, gelatinous product made by concentrating to a suitable consistence the strained juice or the strained water extract from fresh fruit, from cold-pack fruit, from canned fruit, or from a mixture of two or of all of these, with sugar or with sugar and dextrose.

Glucose fruit jelly, corn-sirup fruit jelly, is the semisolid, gelatinous product made by concentrating to a suitable consistency the strained juice or the strained water extract from fresh fruit, from cold-pack fruit, from canned fruit, or from a mixture of two or of all of these, with glucose or corn sirup.

JAMS

The following definition for fruit jam was issued by the United States Food and Drug Administration in 1936.[2]

Preserve, fruit preserve, jam, fruit jam, is the product made by cooking to a suitable consistence properly prepared fresh fruit, cold-pack fruit, canned fruit, or a mixture of two or all of these, with sugar or with sugar and dextrose, with or without water. In its preparation not less than 45 lb. of fruit are used to each 55 lb. of sugar or of sugar and dextrose. A product in which the fruit is whole or in relatively large pieces is customarily designated a "preserve" rather than a "jam."

The above description covers jam made from all fruits, although the small fruits such as raspberries and strawberries are used in larger quantities in this country. At one time it was common practice to use sugar "pound for pound" in respect to fruit, and only cane sugar could be used without other declaration on the label, but this is no longer the case. When fresh fruit is available, it is used for jam production, but many jam manufacturers are far distant from the small-fruit growing areas. In this instance frozen cold-pack fruit, with some sugar added before the mixture is barrel-frozen, often serves as the raw material. Canned fruit may also be used if preferred.

When fresh fruit is used, the fruit which should be of good quality must be thoroughly washed and sorted to remove extraneous materials, stems, hulls, etc. Some of the larger fruits are peeled, cored, or stoned, or may be cooked and when soft, run through pulping machines. When cold-pack fruit is used, it may be heated with water in the kettle in which the jam is to be made without additional preparation. Pectin is sometimes added to give body to the product, and if cold-pack fruit is being used, the pectin should be added to the water and dissolved before adding the fruit. The acidity of the product is sometimes increased by the addition of fruit acids.

[1] S.R.A.F.D. 2, Rev. 4, 1933.
[2] S.R.A.F.D. 2, Rev. 5, 1936, p. 9.

The exact amount of sugar required depends upon a number of factors, including the acidity of the fruit, the sugar content of the fruit, its maturity, and the type of product which is being made. If less sugar is used than may be necessary to bring the final product up to the standards cited above, the label must be modified to indicate properly the nature of the product.

After the preliminary crushing of the fruit or other preparation, the required amount of sugar is added and the mixture is heated in steam-jacketed kettles or preferably in vacuum pans if the fruits have delicate flavors. The heating is continued until the proper boiling temperature is reached, which will depend on the sugar concentration desired in the finished product. In general the finishing temperatures run from 7 to 12°F. above the boiling point of water in the same region. At higher altitudes the boiling point of water is higher than at sea level (212°F.) and therefore the finishing temperatures are correspondingly higher. Care must be taken to prevent heating to the extent that the color or flavor of the fruit is affected, which will occur if this period is prolonged. The smaller the batch, the less likelihood there is of such changes.

Jams for domestic use are commonly packed in glass containers and usually have sufficient sugar content to preserve them against spoilage due to microorganisms. However, they may be heated in the container after sealing if it is necessary. The effect of heating in containers may cause undesirable changes in color and flavor just as readily as these may occur in the kettles, so the containers should be cooled as soon as possible.

Lower grade jams used for bakery products are frequently packed in large wooden pails, in which case the problem of avoiding losses in color is likely to be of greater concern unless cooling is carried out rapidly.

MARMALADE

Marmalades are very similar to jellies, except that they have pieces of fruit peel embedded in the mass. The more common types of marmalade are made from citrus fruits. English marmalades are quite different in flavor from the majority of those made in this country, as the bitter Seville oranges are used in the former. To duplicate the bitter flavor of such English products a combination of orange and grapefruit is utilized. American oranges make excellent products when mixed with lemons. While these fruit combinations make very attractive marmalades from the standpoint of flavor, they are often combined because the lemon or grapefruit furnishes necessary pectin and acid which are sometimes insufficient in oranges alone.

There are several methods which may be followed in making marmalade. According to Cruess, the fruit may be sliced in thin slices, boiled for about an hour to get the fruit tender, and then pressed to remove the

components of these confections and their approximate quantities (Tables 119 and 120).

The principal products of this industry may be divided into chocolates in bulk, chocolate-covered bars, bars other than chocolate-covered, hard candy, caramels, and chewing candy. From the standpoint of value, chocolate-covered bars are the most important. Table 120 indicates the principal states of manufacture of each type in 1931.

TABLE 120.—PRODUCTION OF CANDY

Chocolates in Bulk

State	1,000 lb.	Value, in 1,000 dollars
Total United States	132,897	29,699
Illinois	24,270	5,415
Massachusetts	13,650	3,485
Pennsylvania	19,348	3,425
New York	15,640	3,386
Ohio	13,875	2,305
California	6,542	2,128

Chocolate-covered Bars

State	1,000 lb.	Value, in 1,000 dollars
Total United States	324,319	56,890
Illinois	198,464	32,256
Massachusetts	22,877	5,699
Pennsylvania	21,031	3,745
New York	20,980	3,738
California	8,537	1,784

Bars Other than Chocolate-covered

State	1,000 lb.	Value, in 1,000 dollars
Total United States	62,291	10,522
Massachusetts	10,876	2,012
Illinois	9,567	1,769
Pennsylvania	9,157	1,503
California	4,640	695
Missouri	4,458	568

Hard Candy

State	1,000 lb.	Value, in 1,000 dollars
Total United States	237,038	31,377
New York	34,075	6,333
Illinois	42,274	5,238
Pennsylvania	25,154	3,678
Missouri	12,676	1,403
Ohio	13,286	1,367

Caramels and Chewing Candy

State	1,000 lb.	Value, in 1,000 dollars
Total United States	70,654	10,579
Illinois	20,464	2,406
Pennsylvania	14,572	1,966
Massachusetts	5,733	1,167
New York	5,227	990
Missouri	7,266	964

Chewing gum, which is the product of a closely allied industry using sugar, corn sirup, chicle, and crude gums, is manufactured to the value of over 50 million dollars annually in this country.

The fundamental processes concerned in candy making have much in common regardless of their final form, because in the majority the chief ingredient is sugar. Some of the earlier confections popular in this country doubtless used honey, molasses, maple sugar, and cane sirup as the principal sweetening agents. These same substances are used in some factory-made products even today, but the above group of sweeteners now have a limited usage in comparison with cane sugar or beet sugar.

A number of other sugar products have attained large utilization in the confectionery industry, owing in part to their peculiar chemical qualities and partly from an economic standpoint. Among these are the various by-products of corn such as corn sirup, containing dextrins, maltose, and dextrose in various proportions, depending on the extent to which the starch has been hydrolyzed, and glucose, or dextrose, in a more highly purified form.

Another important sugar product, or in reality a combination of sugars, called "invert sugar" is also important in candy manufacture. Invert sugar is the result obtained from the acid or enzyme hydrolysis or splitting of sucrose (cane or beet sugar), and is composed of equal quantities of dextrose and levulose.[1] The making of invert sugar of proper characteristics for use in candy requires careful control which is, in general, similar to certain methods mentioned in respect to candy processing below.

Lactose or milk sugar is used to a small extent, but condensed milk which also contains the cane sugar that was added in its manufacture is used considerably in candy.

The variety of products is so great that many other ingredients are required in the making of confections, depending on the type being made. Next to sugar itself chocolate is a very common ingredient of many candies. Starches, butter, cocoa butter, molasses, salt, nuts, gelatin, gums, fruit, coconut, many flavorings and coloring materials, and numerous others all have their place in this respect.

It is the sugars present in most candies and the manner in which they have been treated that govern in large part the characteristics of the final products. Sucrose, commonly called refined sugar, whether from cane or beet, is used in practically all kinds of candy and because of its chemical characteristics requires special attention. The grain, transparency, and physical character of the finished product are dependent in large part on the crystal state of the sugar when the process is completed. Some

[1] SCHAAL and JOHNSON, *Food Ind.*, **1**, 268, 1929.

candies must be soft to meet the demands of the consumer, others must be firm and "chewy," while certain types must be hard and brittle. The candy maker must govern his components and their treatment to attain the desired results. Most frequently this means governing his sugar concentrations and the formation of crystal structure.

Sucrose in high concentrations such as are ordinarily used in candy making is extremely likely to crystallize because the solution is supersaturated. Invert sugar differs from cane sugar in that it tends to prevent or retard the crystallization, hence invert sugar is sometimes incorporated in the original mix for candies. Sucrose itself may be converted to invert

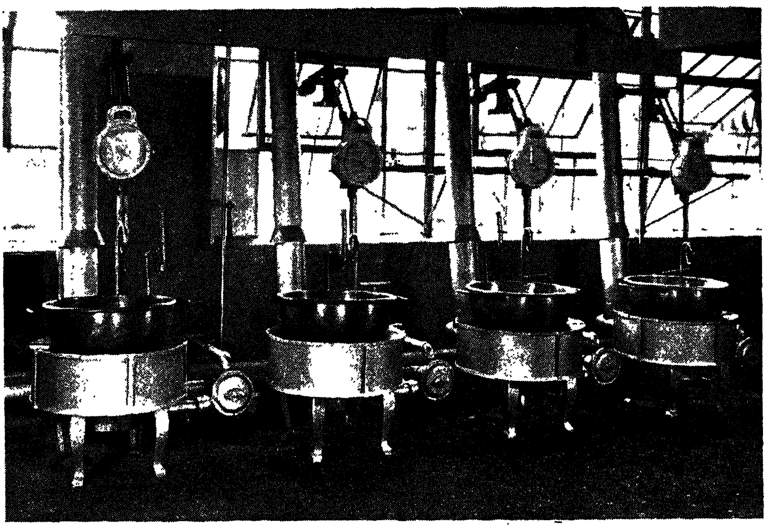

FIG. 66.—Battery of gas-fired candy kettles with recording thermometers. (*Courtesy of Food Industries.*)

sugar during the cooking operations if high temperatures are employed, particularly if acids are present. In some cases this is desirable and agents may be specifically added to aid in this respect. Such agents, of which tartaric and citric acids or cream of tartar are examples, are often extremely difficult to control in their action and depend on time, temperature, pressure, acidity, sugar impurities, and other factors, so that their use is rather limited and uncertain unless one has had wide experience in their use. Even then the results may be problematical. Corn sirup, glucose, or dextrose are also aids in preventing crystallization of sucrose.

Hard Candies.—Hard candies are essentially solid solutions of sugar containing flavoring and sometimes coloring matter. To facilitate the heating and secure uniformity of the mass, water is added at the outset and later it is removed by boiling it off in a vacuum pan. Usually less than 1 per cent moisture remains. Coloring matter is usually added

when the resulting candy is ready to be worked. The flavoring materials are combined with the sugar when the heating is completed if the flavoring is volatile, as in the case of essential oils. When fruit flavors are used, acids such as citric, malic, or tartaric may also be incorporated, but only after the cooking processes are completed in order to avoid stickiness. Synthetic or artificial flavors are often used in such candies.

Hard candies are of several types. Clear candy results unless the product is kneaded or pulled, when the air is entrapped and the material becomes opaque. Sometimes the candy is filled with jam, peanut butter, fruit, chocolate, or some other material, then worked into the desired form.

Caramels.—Caramels are confections which in general are "chewy" in character and are manufactured with this particular quality as a desired objective. In commercial production, dairy products such as milk, cream, evaporated, condensed, or powdered milks, and butter may be used in addition to the invert sugar, cane sugar, and corn sirup. Cocoa butter, being tasteless, can also be used to change the consistency to the desired standards without causing changes in flavor. The general procedure of manufacture is to mix such of the above products as are to be incorporated, sometimes passing them through an homogenizer, after which the entire mass is heated. When the heating is completed, the cooked material is removed from the pan, cooled to room temperature, then refrigerated, and cut into cubes while cold. Many caramels are now automatically cut and packed in the same operation.

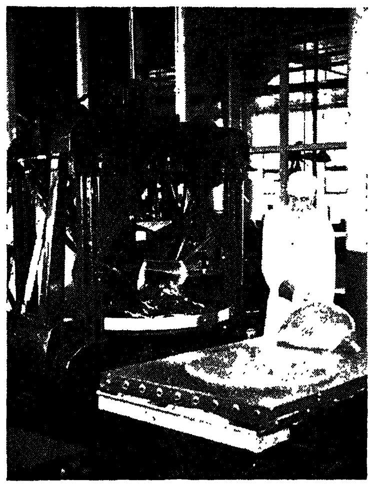

FIG. 67.—Hard-candy cooling slabs and batch mixer. (*Courtesy of Beech-Nut Packing Company.*)

Marshmallows.—Somewhat different from the various kinds of candy mentioned above are the marshmallow products, which are much lighter in character. In making marshmallows the cane sugar, corn sirup, or invert sirup is heated with water and then subsequently mixed with a warm-water solution of gelatin, gum, or albumin. Then the mass is beaten to incorporate air, which is an essential step in the process. After beating, the marshmallow is run into starch moulds to give the desired shape and produce a dry surface. The damage which may be caused by bacteria in gelatin products is lessened by low temperatures and low moisture

content, hence the molding starch should be very dry and practically sterile.

Proper storage conditions are essential for marshmallows as they tend to take on moisture, owing to their hygroscopic qualities. Very low temperatures cause them to become dry and brittle and very high temperatures may soften them unduly. These products are often packaged in moistureproof containers.

Lozenges.—For the manufacture of one type of lozenges or wafers, finely ground cane sugar is moistened with a small quantity of water and mixed until a doughlike consistency is reached. The flavor (and color if any) is then added. The mass is rolled into sheets and the desired forms are stamped out by an automatic cutting device. The moisture in the lozenges is then lowered by appropriate drying equipment. After cooling, the product is packaged.

Another type of lozenge or wafer is manufactured by subjecting finely ground sugar to a high pressure, thereby shaping it into the desired forms. Previous to pressing a small amount of mineral oil, stearic acid, or other binder is mixed with the sugar. The flavoring and coloring materials are added at the same time as the binder.

Gum Work.—Gum drops, the more common forms of gum candy, are now made by boiling soluble starch and sugar in water, whereupon the starch acquires the gumlike body or consistency characteristic of these products. Only enough sugar to sweeten the mixture is incorporated. The heat treatment with constant stirring is continued until the desired physical consistency is reached. When the cooking is completed, the flavoring and coloring materials are added. Portions of the mixture are then run into starch moulds to set, and the surfaces of the pieces are dehydrated by the contact with the dry starch. When the candy has been removed from the moulds, it is sifted and brushed to eliminate excess starch. Then it is rolled in sugar or immersed in a saturated sugar solution to form a glaze or coating which protects the gum from the changes otherwise caused by humidity and temperature variations.

Until within recent years products of a somewhat similar nature were made by the use of gum arabic, but soluble starch has largely replaced the former type of gum. Pectin jells may also be utilized in a similar manner.

Creams.—Fondants are made by heating sugar and water until a supersaturated solution is produced. This is then cooled quickly and immediately beaten to incorporate air into the mixture, thus forming a cream. Crystals from a previous batch of fondant are used in the beater to accelerate the crystallization of sugar during the beating process. The creamed fondant "sets up" or stiffens within a few minutes and is generally allowed to stand overnight, during which period changes occur in the crystal structure and the fondant becomes softer.

The fondant is next melted in a kettle equipped with a stirrer. The sirup batch or "bob" is cooked to a definite temperature in an adjacent kettle. This batch consists of a solution of cane sugar, corn sugar, or invert sugar, or a mixture of these in water, depending on the intended use of the product. The "bob" is then added to the fondant and the mixture is deposited in the moulds of the desired shape which have been previously made in dry starch.

The utilization of starch as in the manufacturing of "cast" confectionery depends in large part on its ability to act as a dehydrating agent, although it incidentally eliminates the necessity of cutting and shaping pieces which would otherwise require special handling. The dehydrating action of starch depends on its ability to absorb moisture which it takes from the hot candy mass when it is run into the moulds. In some cases the room in which this operation is carried out is maintained under controlled conditions of low humidity and temperature, in which case the dry air of the room takes moisture from the starch while the starch in turn absorbs additional moisture from the candy. This is particularly true in the manufacture of certain types of marshmallows, gum drops, and gum arabic candies.

The starch used for moulds is generally cornstarch of edible grade, which may have added to it for moulding purposes just a trace of refined mineral oil. High moisture content or improper handling of the starch hurts its moulding qualities and is likely to cause infections of highly sugar-tolerant yeasts which are likely to "blow" cream centers. It may also favor infection by molds or fungi.

The larger confectionery establishments have automatic machines called moguls, by means of which trays or moving belts may be imprinted with the mould patterns, the moulds filled with candy, and the candies later separated from the starch mechanically when it has sufficiently dried and set. The starch is often conditioned by screening, then drying at 150 to 160°F. between runs to keep its moisture content at an optimum, and leaving the dry starch at proper temperature for moulding use, depending on the type of candy being made.[1]

Centers made in this way are the ordinary cream centers used in chocolates and chocolate creams. The consistency of these centers can be modified to a surprising extent by slight changes in temperature, control, handling, and composition of the ingredients.

Many creams which are later covered with chocolate must be firm and solid when coated but require soft fluid centers when distributed to the trade. This may be accomplished by incorporating a small quantity of fruit acid or invertase in the fondant, which will later invert the sucrose and change the firm texture to a creamy one by forming invert sugar.

[1] WINDT, O. H., *Food Ind.*, **5**, 213, 1933.

Invertase is an enzyme which may be obtained from yeasts and fungi. Its action is very slow at low temperatures, so by refrigerating the product the extent of creaming may be controlled. Unless controlled by refrigeration, these changes may cause losses in the storage of such products before being sold, however.

Chocolate Products.—Many kinds of confectionery contain chocolate as one of the ingredients of either the entire piece or the coating. Chocolate is obtained from the beans found in pods on the cacao trees of tropical Central America, (Costa Rica), Venezuela, Brazil, Ecuador, the Gold Coast of West Africa, the West Indies, including Trinidad, San Domingo, Jamaica, Haiti, Puerto Rico, and the East Indies, (Java), and in Samoa, Ceylon, and Madagascar. The pods contain 20 to 40 of these beans which are first allowed to ferment and are then dried in the sun. The beans are later roasted at 135°C. for about 40 minutes, then cooled, shelled, and broken into "nibs" which are ground by granite buhrstones of special form. The heat of this grinding liquefies the cocoa butter[1] and a rich thick fluid or "chocolate liquor" is formed. Further grinding of this product, often for several days, results in the chocolate of commerce which on cooling is usually made into large slabs or bars.

Milk chocolate is made by dissolving granulated cane sugar in fresh milk, or other milk products, condensing the solution in vacuum kettles heated by steam, to the consistency of a soft taffy. This mass of sugar and milk is now thoroughly mixed with chocolate liquor and the entire mass dried and ground into a coarse powder. Cocoa butter in quantities sufficient to make a paste is next incorporated and the resulting mixture is passed through water-cooled steel rollers and then ground in large oblong tubs with corrugated granite bottoms by means of corrugated granite rollers which are mechanically propelled. This grinding process is continued for several days, after which the mass is moulded in cakes or bars and then wrapped. Nuts may be added just previous to moulding. The moulds are filled at low temperature and finally cooled in tunnels with chilled air.

Cocoa butter, which is the fatty or oily material removed by pressure from chocolate in the manufacture of breakfast cocoa, is used in the manufacture of many confectionery products such as chocolate coatings and sweet chocolate, as well as milk chocolate.

Sweet chocolate contains chocolate liquor, 10 to 30 per cent cocoa butter, and 40 to 65 per cent sugar. Bitter chocolate contains about 15 per cent cocoa butter and sugar varying from 5 to 20 per cent deriving its name from the more bitter flavor resulting.

[1] Cocoa, another product of the cacao bean, and its manufacture are discussed elsewhere in this text.

Chocolates.—Chocolates or chocolate-coated candies are made by coating ("dipping" or "enrobing") various centers of fondant, caramel, marshmallow, nuts, fruit, or other materials with melted liquid chocolate which subsequently hardens. The coating may be made of bitter chocolate, sweet chocolate, milk chocolate, light or dark, at the will of the maker. The basic constituents of all coatings are essentially alike and contain chocolate liquor, cocoa butter, and sugar, with sometimes added flavoring. Milk-chocolate coatings have a somewhat lower melting point, owing to the fact that milk fat melts at a lower temperature than cocoa butter. Lecithin is sometimes incorporated in chocolate coatings to facilitate handling such material as it has a marked effect on the viscosity.

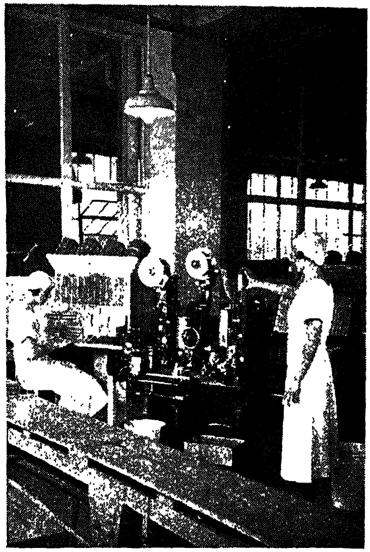

FIG. 68.—Gum-wrapping machine (*Courtesy of Beech-Nut Packing Company.*)

Sanitary Aspects of Confectionery Manufacture.—The sanitary conditions maintained in confectionery establishments are of particular importance as the finished products, unlike those of many food industries, are not subjected to further heat treatment. The presence of insects and rodents is most objectionable from the standpoint of health and also because such pests may cause severe economic loss by the damage wrought on both the confectionery products and the raw materials. Fumigation by gases is sometimes used to eliminate insects in the materials entering candy factories, especially nuts and dried fruits, and for many of the final products.

In addition to the sanitary quality of the raw materials, including sugars, starches, chocolate, gums, egg albumin, milk products of all kinds, fruits, nuts, and other components, it is significant that many confections are subjected to handling by the workers in the packaging operations. Certain covered candies are hand-dipped, although machines are used to a great extent for this purpose at present. It was shown some years ago by Prescott[1] that bacteria of intestinal types could live in various types of candies for considerable periods of time, although the actual numbers undergo constant reduction. Such evidence emphasizes the importance of preventing contamination of confectionery by the handling of employees

[1] PRESCOTT, S. C., Address given at 31st Annual Convention of National Confectioners Association, French Lick, Indiana, 1914.

who may be "carriers" of diseases, especially of the types associated with the intestinal tract.

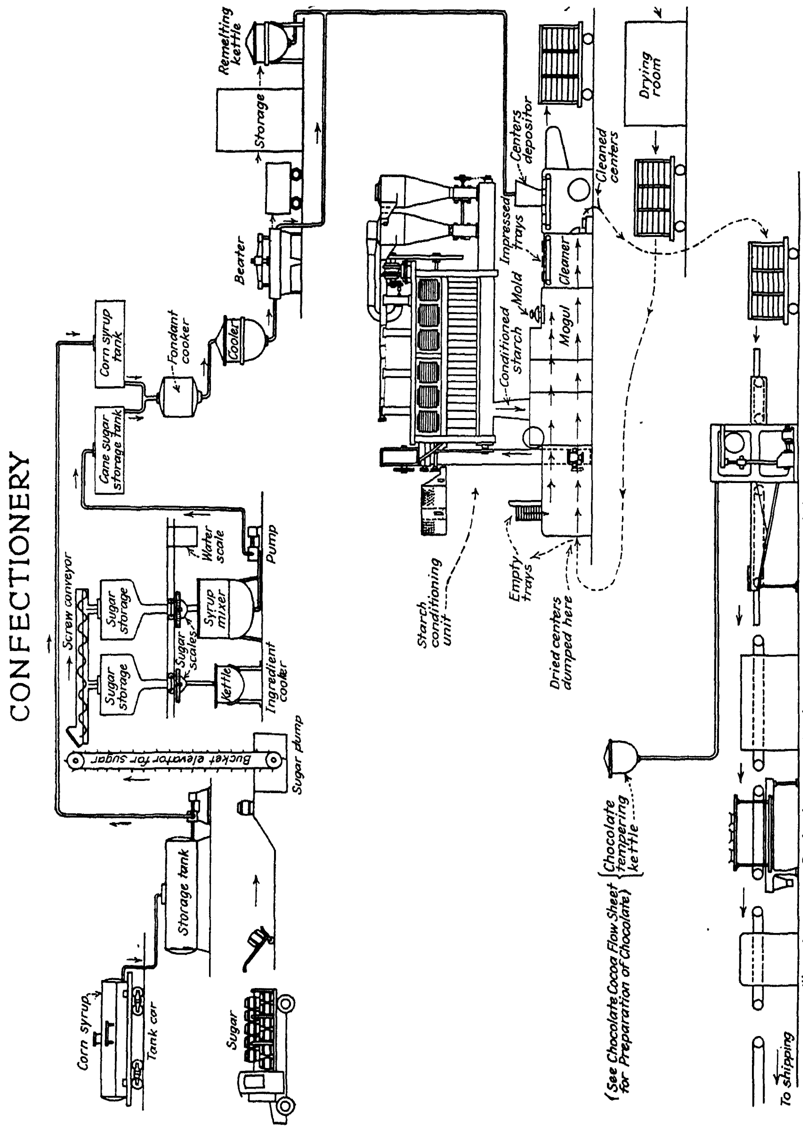

FIG. 69.—Flow chart for confectionery operations. (*Courtesy of Food Industries.*)

The maintenance of scrupulous cleanliness in the plant and rigid control of the personal habits of employees necessary for high sanitary quality are assisted by adequate facilities for hand washing and toilets which are carefully supervised.

Packaging.—A large proportion of the candy manufactured today is packed in small packages. For bulk candy, barrels and pails of wood and of metal are used. Chocolates are widely packaged in boxes, while some hard candies are packed in glass jars and tin cans. The smaller packaged goods are wrapped in wax paper, transparent cellulose wrappers and bags, metal foils, glassine, and similar materials. Such packages offer protection from dirt, dust, and insects, as well as from the handling of the retailer. They also provide protection from physical injury. In certain products the use of moisture-resistant wrapping materials is necessary to prevent undesirable changes in water content which may injure the properties of the finished material and its quality.

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CHAPTER XXII

COFFEE, TEA, COCOA, AND SPICES

COFFEE

Coffee, next to sugar, is the most important product used in connection with foods which is imported to the temperate zones from tropical countries. The plant is probably a native of Abyssinia and other parts of Africa, but was introduced into Arabia in the fifteenth century. The beverage immediately became popular with all classes and from Arabia both the plant and the custom of coffee drinking spread throughout the Eastern Hemisphere and eventually to the Americas. For over 200 years the culture of the coffee tree was limited to Arabia, but in the latter part of the seventeenth century it was introduced into Java by the Dutch and somewhat later into Surinam in South America. From these centers the industry soon spread over the East Indies, India, Ceylon, and Western Africa in the Eastern Hemisphere, and throughout the West Indies, Central America, and certain parts of Brazil in the Western Hemisphere. Today Brazil is the largest coffee-producing country in the world, although some of the best grades still come from Yemen and Sumatra.

The coffee tree is a small tree growing generally to a height of 10 to 15 ft. and belonging to the order Rubiaceae. It produces white and very frequent flowers in the axils of the leaves, these flowers giving place in 8 or 9 months to the fruit which is about the size of a small cherry and which is red or purple, or in some strains yellow, when ripe. In Brazil, the harvesting season generally lasts for four or five months, while in Java where these crops are produced each year, the harvesting is practically continuous. Normally each of these berries produces two seeds so situated that they are flattened together on the inner side, although in some plants one of these seeds is abortive and the other develops into a rounded body practically filling the whole space ordinarily occupied by two—the so-called pea, or male, berry. The outer portion of the fruit is dark-colored and pulpy and is lined by a buff-colored membrane. This material is removed during the curing process, leaving the yellowish or light-green seeds covered with a silvery skin known as the spermoderm. The coffee "bean" is, therefore, the seed of the coffee tree, and it is this portion only which need be further considered. After the seed is dry, the thin membrane is broken and separated from the seed by winnowing, leaving the smooth, waxy-appearing beans characteristic of green or raw coffee.

There are two methods of preparation of the crop known respectively as the "dry" or "natural" and the "wet" or washed methods. For the dry method the berries are frequently stripped from the branches in all stages of maturity from green to overripe, along with leaves and twigs. But for the washed method the full red berries are picked individually from the branches, and the ripe and unripe are separated by a flotation process, the green and malformed berries floating on water and therefore readily removed by skimming.

The dry method is the older procedure. The berries are spread in thin layers on open drying grounds or "barbecues" often provided with cement or brick surfaces. The berries are turned several times daily to permit sun and wind to dry all portions of the berry. After about three weeks of drying, during which they are carefully watched to prevent wetting and overheating or fermentation, the husks of dried pulp are removed by threshing or by special hulling machines.

The wet method produces the so-called "washed coffees" now most common in the trade. This process is practiced on large plantations where there is ample water supply and capital for the extensive and costly machinery required. By this process the freshly picked coffee berries are dumped into tanks from which they are floated by streams of running water directly into the hoppers of pulping machines, the purpose of which is to remove the outer skins and pulp. Sometimes the berries are soaked over night in tanks full of water in order to soften the outer skins and make them more easily removable by the pulping machines. The variation in size of the fruits makes perfect removal of the pulp difficult, but careful adjustment overcomes this to a great extent and excellent results are attainable.

The pulped berries are then run into tanks filled with water where they undergo a fermentation lasting from a few hours to days. This fermentation breaks down saccharine substances and loosens the slimy inner part of the pulp which can then be removed by washing. The seeds or beans still in the parchment or "silver skin" are then spread on drying platforms as in the dry method or by the use of special types of drying machinery which operate efficiently and save much time and which can be used in rainy as well as sunny weather. In the drying operation the parchment is so dehydrated that it can be easily removed, which is done by another type of machine in which the friction on a rough surface and the rubbing of the beans against each other break the dry skin and leave the beans clean. Sieves and exhaust fans remove the fragments of the parchment. After this the coffee is cleaned by a pneumatic separation process and graded according to size and quality of beans. This may be done in part by automatic sizing machines, but the final grading in which the undesirable beans are removed is accomplished by hand as the coffee

passes along a belt in front of the women and children who are trained to detect the unsound and imperfect beans.

Thus the green coffee of commerce may be prepared by either the wet or the dry method. It varies greatly in color and size of bean, and also in its quality as the source of the familiar beverage. The quality is to a large degree dependent on soil and climatic conditions.[1]

The structure of the seed is interesting and complex, being made up of several layers of cells of different shapes in which are stored up the reserve foods for the embryo plant when it develops. These layers constitute the so-called endosperm of the seed, which is the important part from the standpoint of coffee production. Unlike many seeds, coffee does not contain large quantities of starch, the reserve materials being largely in the form of cellulose stored up in the cell walls of the endosperm, together with some sugar and other nitrogen-free extractives. Other cells contain certain oily or waxy substances and nitrogenous materials, and chlorogenic acid and other bodies of a similar character are also present to some extent. Opinions differ as to the identity and quantity of these substances.

Before using coffee for beverage purposes, it must undergo the process of roasting, during which the seed swells somewhat, its color is changed to dark brown or almost black, depending upon the severity of the roast, and it acquires the characteristic odor and flavor of roasted coffee, which is supposed to be due to the formation of esters of chlorogenic acid, furfuryl derivatives and some other aroma-giving substances. Essential as these are, the importance of coffee as a beverage material is very largely due to the fact that it, in common with tea, contains considerable portions (1 to 2 per cent) of the so-called alkaloid caffein (trimethylxanthin) which has marked stimulating properties and may be regarded as the most significant of the ingredients in the seed. It will be at once clear that coffee varies greatly in composition, depending upon the type of coffee, the region from which it comes, altitude, soil, and many other factors. No given set of figures will represent exactly the analysis of more than a single sample or of a single lot, owing to these numerous factors.

Coffee roasting, which was formerly a domestic process, has in the past 50 years developed into a vast business, with special types of machinery, and utilizing coal, coke, gas, oil, or electricity as the source of heat. The process of roasting transforms the green horny beans, with practically no odor and almost impossible to taste because of their physical character, into crisp brittle brown units which have their characteristic odor and flavor developed in varying degrees according to the duration of the heat

[1] For a detailed account of coffee see All About Coffee, by William H. Ukers, 1935. Published by the Tea and Coffee Trade Journal Co., New York.

applied, and of course also depending upon the inherent differences in the coffees from the various parts of the world. In certain countries, as in Italy and Turkey, the coffee is roasted almost to the point of blackness in color, while in the more northern regions a lighter roast is preferred. There are, therefore, many standards of roasting, depending upon the preferences of the consuming public. Roasting is often preceded by a very careful blending of different types of coffee in order to secure the especial taste or flavor which a particular section of the trade demands. Since Brazil produces approximately 70 per cent of the world's coffee, most of the common blends contain a large proportion of coffees from this country, with smaller proportions of the products from other parts of South America, Mexico, Central America, or the East Indies. Coffee roasting has become highly developed in the United States, Germany, Holland, and France, but other countries also have made great strides in this respect. Many different types of roasting equipment have been evolved, with automatic devices for control of heat, for timing, and for otherwise standardizing the procedures. As a result the product shows little variation from day to day, although there may be obvious minor differences when the crops of a given season are exhausted and are replaced by new importations.

The roasting is carried out at different temperatures, ranging from 200 to 250°C., but it is best around 200°C. or below. During the roasting there is a large loss in water content, the sugar is probably caramelized and largely disappears, and there is also a large loss in the crude fiber, owing to the process of destructive distillation which takes place. The loss in caffein is believed to be small, as is also the loss in fatty substances and ash. About 90 per cent of the loss is in water and crude fiber, while there is a slight percentage gain in nitrogenous substances, owing to the fact that these are not broken down or at least driven off during the heating process, while there is a considerable loss in the actual weight of the coffee. Some authors have assumed that sugar is formed during the roasting, and that this is again partially broken down. Figures on the exact percentage composition of coffee are impossible since it has been shown by numerous investigators that slight differences in technique give widely different results.

In addition to roasting, grinding and packaging have become of great importance in the industry. With the general tendency to reduce the work of preparation in the consumer's home, the use of ground coffee has become almost universal, although it is recognized by experts that the best beverage coffee is that prepared from freshly ground beans which are also freshly roasted. Ground coffee undergoes a loss of flavor and development of staleness if long exposed to air, the changes becoming detectible to the careful taster even after three or four days of such con-

tact. Bean coffee, because of the intact exterior surface, will change more slowly. These facts are of great significance in packaging and many attempts have been made to secure long-keeping quality before sale by improvement in the packaging material. The most successful of these attempts has been brought about by the use of the "vacuum pack" in tin cans, hermetically sealed. But after opening such a can the coffee is subject to the gradual reaction with oxygen which seems to be responsible for the development of staleness. Coffee is therefore a commodity which should be bought by the consumer in small quantities at a time—a week's supply or less, rather than in large amounts.

It is impossible to present any scheme or plan of analysis which is representative of general procedure, as these vary with different chemists, and hardly any two follow exactly the same detail. The greatest variation of opinion is held as to the way in which caffein occurs, some authorities believing that it is in free condition, while the majority hold that it occurs united with tannic and caffetannic acids. The caffein content is quite variable, variations of 250 per cent having been noted. Lendrich and Nottbohm claim that certain wild coffees contain much more caffein than cultivated varieties.[1] They also claim that this substance occurs not only in the seed itself, but in small amounts in the shell and seed coats. Perrot describes five crystalline principles derived from coffee which are of importance in its use as a beverage, namely, caffein, potassium chlorogenate, coffalic acid, valeric acid, and trigonellin. Several other chemists have claimed to have isolated and identified trigonellin and the salts of chlorogenic acid, but are not positive on the occurrence of the other principles cited above. All authorities agree on the occurrence of the definite substance caffein, although as has been stated, there are widely divergent methods for its determination. Since roasting brings about deep-seated changes, it might be expected that there would be found many products not occurring in the green bean. Here again there is a multiplicity of opinions as to the character of the changes which are brought about. A number of investigators have described pyridine-like bodies, furfuryl, furfuralcohol and certain substances described under the name of "coffeol" which may be either a pure substance or more likely a mixture of volatile alcohols and derivatives. Thus Grafe states that the furfuralcohol is derived from the hemicellulose of the endosperm and is one of the constituents of coffeol. He also believes that the furfuralcohol is obtained in smaller quantities with high roasting than with moderate roasting.

The ash of coffee is alkaline in character, consisting largely of the phosphate and carbonate of potash, although in Mocha coffee salts of magnesium and calcium are also found.

[1] See Coffee Research, *Am. Food J.*, April 1923, p. 167.

Oils and fatty substances are present in coffee in considerable quantity, although the exact nature of these is still in doubt. Hartwich, in an investigation on these substances, came to the conclusion that the fats were mostly olein, with small amounts of palmitin and stearin. Meyer and Eckert separated two sets of fatty substances, first, those which are saturated with oxygen, of which they assume that compounds of palmitic acid make up 25 to 28 per cent, compounds of carnaubic acid, 20 per cent, daturic acid, 1 per cent, and capric acid, 5 per cent. According to these authors, the saturated acids make up 40 per cent of the total fatty matters in coffee. Of the unsaturated fats, compounds of oleic and linoleic acids comprise the greater portion, linoleic acid or its compounds making up 50 per cent of the total fatty material. They also assume the presence of carnaubic wax and some resins. A few other investigators who have worked on this phase of the subject believe that an oil to which the name of caffeol has been given is present in combination in roasted coffee and is liberated by the action of steam or hot water. Grafe assumes that the total aroma-giving substance of coffee is due to caffeol and another substance, caffeone. He assumes that the caffeol is derived directly from the raw fiber during the process of roasting, that it is closely associated with the caffein, and that much is lost in the preparation of caffein-free coffee.

Recent unpublished work carried out at the Massachusetts Institute of Technology has identified the following substances in roasted coffee: kahweol, diacetyl, diethyl ketone, vanillone, p-vinyl guaiacol, guaiacol, n-heptacosane, p-vinyl catechol, sylvestrene, eugenol, a hydrocarbon of m.p. 116–117°C.

Some of these have been previously reported in the literature and their presence confirmed by the present work. Others have not been previously mentioned.

Table 121 gives the seven principal exporting countries with their respective exports for the years indicated.

TABLE 121.—COFFEE EXPORTS: LEADING COUNTRIES
(1,000 lb.)

Country	Average 1930–1934	1934
Brazil	875,688	1,871,309
Colombia	419,629	415,728
Dutch East Indies	174,700	180,409
Salvador	114,182	109,935
Venezuela	110,626	75,350
Guatemala	96,452	77,891
Haiti	70,369	75,018

Brazil exports, according to these figures, more than twice the amount of coffee that the other four leading countries together export. Brazil also exports nearly five times as much coffee as her nearest rival, Colombia.

In 1933, Mexico produced more coffee than either Haiti or Guatemala. Costa Rica, Nicaragua, British India, Dominican Republic, and Jamaica also export coffee.

TABLE 122.—PRINCIPAL COFFEE-IMPORTING COUNTRIES

Country	Average 1925–1929, 1,000 lb.	1930, 1,000 lb.
United States	1,429,825	1,599,317
France.......	360,039	394,396
Germany....	266,650	340,310
Netherlands..	113,722	100,918
Italy.........	99,761	99,863

The United States imports nearly four times as much coffee as France, and more than France, Germany, Netherlands, and Italy together. The sources from which the United States receives its principal supply are shown in Table 123.

TABLE 123.—SOURCES OF UNITED STATES COFFEE
(1,000 lb.)

Country	1926–1927	1931–1932
Brazil...............................	1,000,721	1,158,566
Colombia............................	313,590	334,105
Central America......................	40,070	31,923
Venezuela...........................	43,436	45,849
Other countries......................	47,030	58,398
Total............................	1,444,847	1,628,841

An examination of this table shows that two-thirds of our coffee is imported from Brazil, about one-fifth from Colombia, and the rest from Central America, Venezuela, and other countries.

A comparison of the amounts of coffee and tea imported into this country demonstrates quite vividly that this is a coffee-drinking nation, rather than a tea-drinking one.

TEA

The tea plant (*Thea sinensis*) grows in moist subtropical regions having 60 in. or more of rainfall per year. It is an evergreen, and flowering is

permitted only when seeds for propagation are desired. The leaves or young shoots are the material which is used for tea.

With the exception of water, the tea-leaf infusion is used as a beverage by greater numbers of people than any other beverage. The Chinese have probably used the leaf for over 4,000 years. Tea was introduced in the thirteenth century into Japan. It was imported to Europe in the sixteenth century. First mention was made of tea in England in 1657. Some of the first tea sold for $50 a pound. Later, in 1673, tea was imported in commercial quantities and the price dropped to around $5 a pound for some of the cheaper grades of tea carried to the American colonies. The tax imposed by our mother country on this highly regarded beverage was the cause of the historic and famous "Boston tea party."

Seeds of the tea plant are germinated in a nursery. When the plants are 6 to 12 in. high, they are transplanted to rows 4 ft. apart out in the open fields. Some varieties of the plant may grow to a height of 30 ft., but the usual height is restricted to 3 or 4 ft. The height of the plant is determined, of course, largely by the species, the locality, the climate, and the amount of pruning.

Although maturity of the plant depends upon soil conditions, rainfall, and amount of sunlight, the tea plant is generally ready to have the desirable leaves picked, *i.e.*, to yield a crop, three to four years after the plant has been set out. In order to obtain optimum results, the tea plant is pruned frequently to stimulate the production of a stocky plant with many new shoots. In some localities, leaves may be picked as many as 25 times a season, and with proper care a plant may bear well for 50 years.

Table 124 shows the principal exporting countries for tea.

TABLE 124.—TEA PRODUCTION
(1,000 lb.)

Country	Average 1925–1929	1930
British India	364,848	365,344
Ceylon	228,445	243,021
Dutch East Indies	124,947	137,573
China	116,300	91,358
Japan	24,631	20,316
Formosa	20,431	17,619
Total	879,602	875,231

An examination of the table shows that over 40 per cent of the tea for exportation is raised in British India and about 25 per cent in Ceylon.

The six leading importing countries with their imports are given in Table 125.

TABLE 125.—TEA IMPORTS: LEADING COUNTRIES
(1,000 lb.)

Country	Average 1925–1929	1930
United Kingdom	429,507	452,763
United States...	93,052	84,926
Australia........	49,242	50,028
Russia..........	43,287	53,411
Canada.........	38,268	50,886
Netherlands.....	26,144	29,587

The United States imported tea in the quantities noted from other countries, as shown in Table 126.

TABLE 126.—UNITED STATES TEA IMPORTS

Country	1926–1927, 1,000 lb.	1931–1932, 1,000 lb.	Per cent
Japan................	28,430	22,927	25.3+
United Kingdom.......	22,136	23,340	25.8
Ceylon...............	16,578	16,855	18.6
China................	11,655	7,329	8.1+
British India..........	8,059	9,886	10.9+
Netherland East Indies	7,660	6,637	7.3+
Other countries........	2,884	3,485	3.8+
Total...............	97,402	90,459	

The large importation from the United Kingdom represents for the most part tea grown in British possessions. It seems to be further obvious from the tables given that the United States is the principal customer for the Japanese tea producers.

Fully developed tea leaves have the following percentage composition, according to Konig:

TABLE 127.—COMPOSITION OF TEA LEAVES

Water	9.51
Nitrogenous substances	24.50
Theine (caffein)	3.58
Essential oil	0.68
Fat, chlorophyll, and wax	6.39
Gum, dextrin, etc	6.44
Tannin	15.65
Pectin, etc	16.02
Crude fiber	11.58
Ash	5.65

Of the above materials, theine—which is a trimethyl xanthine identical with the caffein of coffee—, tannin, and the essential oil impart the characteristic qualities to the tea infusion. It is the volatile portion of the oil which undoubtedly aids mostly in the resultant flavor.

Two main kinds of tea appear on the market: green and black teas. These teas may be manufactured from the same raw material, and their differences are due to the methods of preparation.

Both teas are subjected to withering, rolling, and firing. Green tea is withered by the use of dry artificial heat or by steaming at a temperature below 212°F. Withering is designed to render the leaf soft and flaccid for twisting. Withering is hastened in the production of green tea in order to prevent the development and action of the tea enzymes producing the changes which are desirable in black tea. The shoots are next rolled. The leaf is twisted and forms a "roll," and many of the cells are broken during this treatment. At this time the "rolls" may be permitted to "sweat" or undergo a spontaneous heating in heaps for a short period. The "rolls" are broken up by passing them through a roll breaker, after which detached leaves and stems are sifted through a wire mesh into a cloth container. The tea leaves are next spread out thinly on wire trays or moving belts and dried by passing a current of air which has been heated to from 190 to 240°F. through the trays, or by the use of drying chambers. The foregoing treatment causes a retention of the green color and flavor. The material is sorted by sieving and then packed, or it may be roasted again after grading and before the packing operations. Grades of tea are determined by the position of the leaf on the shoot, the age of the leaf, the size of the leaf, etc. The large-sized leaves form the cheaper grade of tea.

Black tea is prepared first by withering the tea in the air, if the humidity is not too high, thereby stimulating the development of the enzyme (an oxidase). This enzyme is present in the largest quantities in the tips of the young leaves and least in old leaves. The leaves are piled in heaps to ferment for a few hours. Experts decide by the appearance and smell when the fermentation or oxidation is complete. Too short a fermentation period results in the tea having a raw or bitter flavor, while too long a period causes a partial or complete destruction of flavor. Heating and rolling follow fermentation, then exposure to the sun. The tea is again roasted and rolled. After the third roasting and rolling, the tea is ready to be sifted, dried, and packed for distribution.

Black tea contains considerably less tannin than green tea as a result of the special treatment outlined above.

The following definition of tea is given in S.R.A.F.D. 2, Revision 4, 1933:

Tea is the tender leaves, leaf buds, and tender internodes of different varieties of *Thea sinensis* L., prepared and cured by recognized methods of manufacture.

It conforms in variety and place of production to the name it bears; contains not less than 4 per cent nor more than 7 per cent of ash; and meets the provisions of the act of Congress approved March 2, 1897, as amended, regulating the importation and inspection of tea.

COCOA

*Cacao beans, cocoa beans, are the seeds of trees belonging to the genus Theobroma, especially those of *Theobroma cacao* L., and closely related species.

Cacao nibs, cocoa nibs, "cracked cocoa," are roasted or dried cacao beans, broken and freed from germ and from shell or husk.

Cacao butter, cocoa butter, is the edible fat obtained from sound cacao beans, either before or after roasting.

Chocolate, plain chocolate, bitter-chocolate liquor, chocolate paste, bitter-chocolate coating, is the solid or plastic mass obtained by grinding cacao nibs, and contains not less than 50 per cent of cacao fat and, on the moisture- and fat-free basis, not more than 8 per cent of total ash, not more than 0.4 per cent of ash insoluble in hydrochloric acid, and not more than 7 per cent of crude fiber.

Sweet chocolate, sweet-chocolate coating, is chocolate mixed with sugar and/or dextrose, with or without the addition of cacao butter, spices, or other flavoring materials, and contains, on the moisture-, sugar-, and fat-free basis, no greater percentage of total ash, ash insoluble in hydrochloric acid, or crude fiber, respectively, than is found in moisture- and fat-free chocolate.

Milk chocolate, sweet milk chocolate, is the product obtained by grinding chocolate with sugar and/or dextrose, with the solids of whole milk, or the constituents of milk solids in proportions normal for whole milk, and with or without cacao butter, and/or flavoring material. It contains not less than 12 per cent of milk solids.

Cocoa, powdered cocoa, is chocolate deprived of a portion of its fat and pulverized, and contains, on the moisture- and fat-free basis, no greater percentage of total ash, ash insoluble in hydrochloric acid, or crude fiber, respectively, than is found in moisture- and fat-free chocolate.

"Breakfast cocoa" is cocoa which contains not less than 22 per cent of cacao fat.

Sweet cocoa, sweetened cocoa, is cocoa mixed with sugar and/or dextrose, and contains not more than 65 per cent of total sugars in the finished product, and, on the moisture-, sugar-, and fat-free basis, no greater percentage of total ash, ash insoluble in hydrochloric acid, or crude fiber, respectively, than is found in moisture and fat-free chocolate.

Sweet milk cocoa is the product obtained by grinding cocoa with sugar and/or dextrose, with the solids of whole milk, or the constituents of milk solids in proportions normal for whole milk, and with or without flavoring material. It contains not less than 12 per cent of milk solids.

Dutch-process chocolate, "alkalized chocolate," and Dutch-process cocoa, "alkalized cocoa," are modifications, respectively, of chocolate and cocoa, in that in their manufacture an alkali carbonate or other suitable alkaline substance

*S.R.A.F.D., 2, Rev. 5, 1936.

has been employed. In the preparation of these products not more than 3 parts by weight of potassium carbonate, or the neutralizing equivalent thereof in other alkaline substance, are added to each 100 parts by weight of cacao nibs. The finished products conform to the standards for chocolate and cocoa, respectively, due allowance being made for the kind and amount of alkaline substance added.

Cocoa and chocolate are secured from the cacao (tree) or Theobroma tree. Cacao is an old Mexican name, while Theobroma (the name given to the tree by the great botanist, Linnaeus,), means "food of the gods."

The cacao tree grows best in a soft soil containing abundant moisture and humus. A minimum of about 45 in. of rainfall a year, if uniformly distributed, is sufficient, but in Java where the cacao thrives, as much as 150 in. of rainfall is common. The cacao tree grows best in the mean temperature range of 77 to 83°F. with an average maximum of approximately 90°F. and an average minimum of approximately 70°F. A warmer climate is necessary than for coffee and tea cultivation.

Since cacao trees are often found growing sheltered by other trees, it is customary to plant them in many cases in the shade of banana or coral trees, or else close together. Trees are also set out in clearings made in the dense tropical underbrush. It has been found that a partial shade is beneficial, although cacao trees are grown successfully in some regions without any shade from other trees.

The cacao tree attains a height of approximately 20 ft. when mature with a trunk 5 to 10 in. in diameter. The tree may be propagated from seeds, from seedlings or by grafting or budding. Pods, containing 30 to 60 beans, are borne on the branches and the stem. Owing to the fact that the pods are loosely attached to the tree, the cacao trees cannot generally be grown profitably in regions where there are strong winds, unless cultivated in secluded spots. Nevertheless, in spite of this hazard, cacao trees are cultivated at certain seasons in the Philippines and West Indies, in regions where high winds are not uncommon.

Cacao trees are indigenous to the New World. Ecuador, parts of Brazil, Venezuela, and Colombia, and the neighboring island of Trinidad are particularly suited to the cultivation of these trees. The African Gold Coast, the islands of St. Thomas and Principe, Ceylon, San Domingo, Panama, and Mexico also produce cacao in quantity. The Gold Coast is outstanding and in 1930 produced 60 per cent of the world supply.

The pod of the cacao tree is not particularly attractive when opened. The seeds are covered with a slimy or fruity pulp, containing sugar and other nutrient materials suitable for fermentation by microorganisms.

The seeds are freed of the moist pulp by a spontaneous fermentation, during which the germ of the cacao bean is destroyed by the heat evolved. A temperature of 104 to 122°F. stimulates enzyme action and at the same time destroys the germ, thus preventing subsequent germination of the

seed. If the temperature is permitted to rise excessively during the fermentation, enzymes, as well as the germ, are destroyed.

Enzymes bring about changes in the composition of the bean. The astringent taste due to tannins is greatly reduced, and color and characteristic aroma are developed.

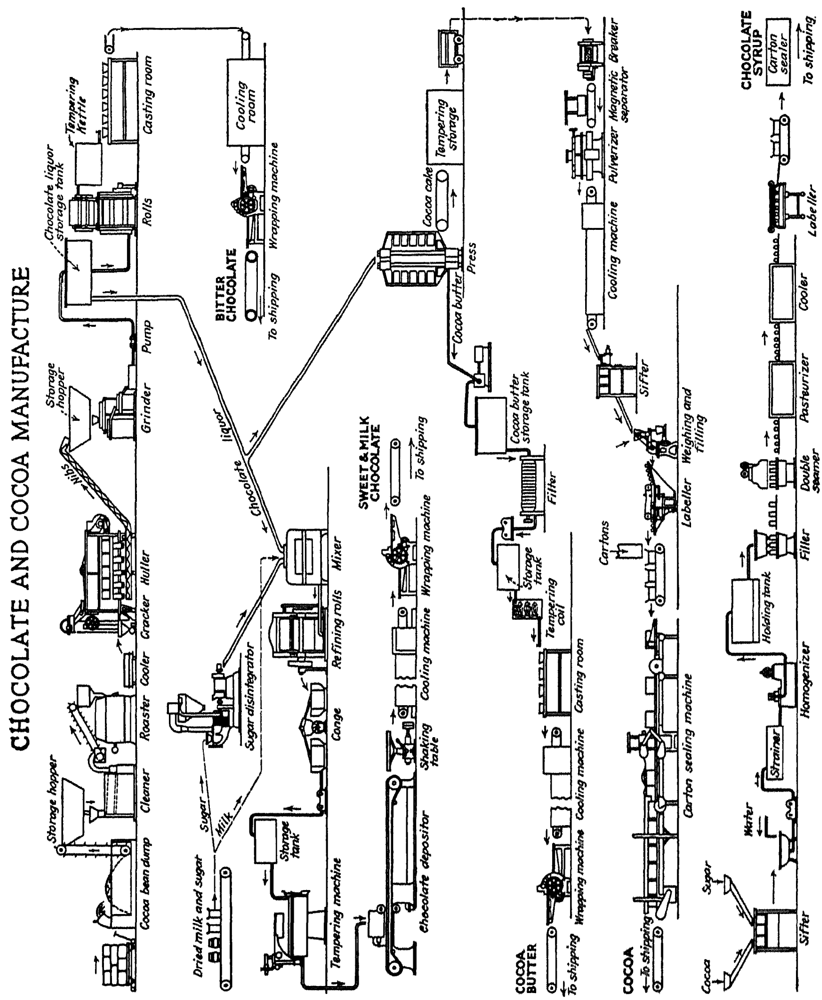

FIG. 70.—Flow chart of chocolate and cocoa manufacture. (Courtesy of Food Industries.)

There is considerable variation in the nature of the fermentation, depending upon the locality and the organisms concerned. It is common, however, for an alcohol fermentation to take place first, followed by an acetic acid fermentation. During the fermentation period, there is often a loss in weight of the beans and hence a tendency to shorten the process. If the fermentation is unduly short, there is an odor of vinegar

in the beans, if too long, unpleasant flavors and odors are produced, so experience and discretion are important in handling the product successfully.

Following fermentation, the beans are dried and then roasted. Roasting renders the shell of the cacao bean brittle and dry, and the shell can then be easily removed from the kernel by cracking the bean. The shell of the cacao bean is fibrous, contains little or no food value and is indigestible; it is therefore essential to remove it entirely from the kernel.

During roasting, flavor and aroma are developed, the color becomes darker, bitterness is reduced through volatilization of the acids produced during fermentation, and tannins are converted into nearly tasteless

TABLE 128.—CHOCOLATE AND COCOA PRODUCTS, 1929

Class	Pounds	Value
1. Chocolate- and cocoa-products industry, all products, total value		$119,540,693
2. Chocolate, cocoa, etc		$118,211,853
3. Other products		1,328,840
4. Chocolate, cocoa, etc., made as secondary products in other industries, principally the confectionery industry, value		1,147,442
Chocolate, cocoa, etc., all industries, aggregate value (sum of 2 and 4)		119,359,295
Chocolate		
Total value		97,148,605
Unsweetened	10,773,480	3,698,675
Sweet and milk chocolate, total	142,210,408	44,504,883
Sweet chocolate:		
Plain	17,879,826	$ 5,018,438
With nuts, etc	4,935,590	1,423,927
Milk chocolate:		
Plain	63,663,219	18,927,556
With nuts, etc	51,764,861	18,120,800
Not separately reported as to kind (sweet or milk, plain or with nuts)	3,966,912	1,014,162
Coatings, total	266,855,296	48,945,047
Sweet	148,195,534	$ 25,054,543
Milk	93,538,153	19,252,764
Liquor	25,121,609	4,637,740
Cocoa, powdered, total	105,693,979	15,053,947
In cans of 1 lb. or less	35,767,333	8,222,497
In cans of more than 1 lb	8,912,105	1,386,935
In barrels and drums	61,014,541	5,444,515
Cocoa butter	19,183,691	5,428,548
Other chocolate and cocoa products, value		1,728,195

substances. Obviously there is a loss of moisture during roasting. This heat treatment also destroys the eggs and larvae of the cacao moth, if such are present.

Fat, protein, starch, and tannin are present in the cacao bean. The fat varies but may be as high as 55 per cent of the bean, and contains chiefly the glycerides of stearic, palmitic, lauric, and arachidic acids, this mixture forming the product known as cocoa butter, which is used in the manufacturing of candy and pharmaceutical preparations. Theobromin, the stimulating principle of chocolate and cocoa, is a purine base, dimethylxanthine, and is present in quantities of 1 to 2.65 per cent. The brown color of cocoa is largely due to oxidized tannins.

The cacao bean is the source of chocolate and cocoa, the latter name being given to the ground seeds after a large portion of the fat or "cocoa butter" has been pressed out or removed.

Several modifications of cocoa are on the markets. In the Dutch method for the manufacture of "soluble" cocoa (which is said not to be rendered soluble) the fat may or may not be removed, the roasted-bean powder is treated with an alkali such as potassium or sodium carbonate. A German process uses ammonium carbonate, $(NH_4)_2CO_3$. Cocoa is said to be superior if 30 per cent of the original fat is present. Chocolate and cocoa factories are most frequently located near dairy centers in the European countries of Holland, Switzerland, England, France, and Germany, as much of the product is combined with milk to form the well-known milk chocolates, etc., as well as the other types of cocoa foods.

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SPICES AND CONDIMENTS

Spices and condiments are aromatic or savory vegetable substances used to impart special taste or relish to food, or to serve as appetizers or seasoning agents. It is possible that they may on occasion be used to hide natural flavors, to cover the defects of poor cooking, or to improve food preparations of an inferior grade. Condiments are not necessary as articles of food for the human body. The essential or volatile oils are responsible in large part for the characteristic taste and individuality of the particular condiment.

Condiments may be classified according to the part of the plant from which they originate. From the roots of plants come ginger, garlic, sassafras, horseradish, and turmeric. Sage, peppermint, spearmint, thyme, tarragon, wintergreen, bay leaf, sweet marjoram, and similar condiments come from the stems and leaves. Barks furnish cinnamon

and cassia. Cloves, saffron, and capers are secured from flowers or buds. Immature and ripe fruits are the sources of allspice, paprika, capsicum, pepper, juniper, and the vanilla bean. Finally from the seeds are obtained such condiments as nutmeg (mace), mustards, paradise, cardamom, bitter almonds, anise, the tonka bean and the cumin, coriander, and celery seeds.[1,2]

Ginger.

Ginger is the washed and dried, or decorticated and dried, rhizome of *Zingiber officinale* Roscoe. It contains not less than 42 per cent of starch, not more than 8 per cent of crude fiber, not more than 1 per cent of lime (CaO), not less than 12 per cent of cold-water extract, not more than 7 per cent of total ash, not more than 2 per cent of ash insoluble in hydrochloric acid, nor less than 2 per cent of ash soluble in cold water.

Jamaica ginger is ginger grown in Jamaica. It contains not less than 15 per cent of cold-water extract, and conforms in other respects to the standards for ginger.

Limed ginger, bleached ginger, is whole ginger coated with carbonate of calcium. It contains not more than 4 per cent of carbonate of calcium nor more than 10 per cent of total ash, and conforms in other respects to the standards for ginger.

Ginger may be grown in suitable moist places in all tropical climates. It is cultivated in China, Japan, the East and West Indies, Africa, Australia, and is a native of India and China.

Ginger is an annual herb and grows to a height of 3 to 4 ft. When the plant is a year old and after the stem has withered, the roots are dug. The root is scalded to prevent sprouting and dried quickly. The article thus formed is known as black ginger.

Jamaica ginger (white ginger) is obtained by peeling or scraping the fresh rhizomes, macerating in water and drying in the sun. The peeled roots may be bleached with sulphur, or dipped in limewater, or calcium sulphate and water, to whiten, and then dried. Inferior grades of ginger are often bleached.

The starch, volatile oil, and resinous material in ginger are characterizing features. Flavor is due in large part to the volatile oil; pungency to the resinous matter. Since the epidermis contains much resin, decorticated ginger is inferior ginger.

Garlic.—Garlic, *Albium sativum*, owes its particular flavor to an essential oil, consisting principally of allyl sulphide (C_3H_5S) or allyl sulpho-

[1] See Spices and Condiments, by James B. McNair, 1930. Field Museum of Natural History, *Botany Leaflet* 15, for a botanical description of other spices.

[2] Unless otherwise noted the definitions for spices and condiments are as cited in the Service and Regulatory Announcements, U. S. Dept. of Agriculture, No. 2, revision 4, August, 1933.

cyanide (C_3H_5NCS). Garlic is raised in Europe and in the United States, and is used extensively by South Europeans in cooking, especially with meat products.

Sassafras is the bark of the stems, trunk, and roots of *Sassafras variifolium.* The bark of the root is considered best. (The volatile oil may be extracted before use.) The sassafras tree grows along the Atlantic seaboard and inland. It is used particularly in carbonated beverages.

Horseradish is the root of a plant, *Cochlearia armoracia* L. Its flavor is due largely to a volatile oil made up principally of butyl sulphocyanate (C_4H_9CNS), which is dissipated by exposure to light and air. The root may be grated and preserved in vinegar.

Curcuma, turmeric, is the dried rhizome or bulbous root of *Curcuma longa* L.

Turmeric (*Curcuma longa*) is native to Cochin China and the East Indies and a member of the Zingiberaceae family to which ginger belongs. The rootstock is perennial. The root is the portion of the plant used; this is dried and ground up thoroughly. Turmeric is used for both its flavor and coloring matter. The coloring matter (curcumin) is yellow. Besides curcumin, the principal constituents are starch, a volatile oil, gum, and cellulose. Turmeric has been used as an adulterant of ginger and mustard.

"**Sage** is the dried leaf of *Salvia officinalis* L. It contains not more than 12 per cent of stems (excluding petioles) and other foreign material." Flavor is due in large part to the presence of an aromatic oil in the leaves. This oil possesses properties of an astringent and tonic to a small degree. Sage grows wild in certain parts of Southern Europe.

"**Peppermint** is the leaves and flowering tops of *Mentha piperita* L. Oil of peppermint is the volatile oil obtained from peppermint and contains not less than 50 per cent by weight of menthol."

Peppermint plants are cultivated intensively in some states in order to obtain the oil. Michigan and Indiana are the leading producers and produce nearly 50 per cent of the world's commercial supply of peppermint and spearmint oils. The peppermint plant is indigenous to many countries in the temperate zone and may be found growing wild in locations of sufficient moisture. Peppermint and spearmint are used principally in medicine, confectionery, and chewing gums.

"**Spearmint** is the leaves and flowering tops of *Mentha spicati* L. Oil of spearmint is the volatile oil obtained from spearmint." Spearmint is native to Asia and Europe but may be seen growing in moist places in some sections in the Northern part of this country. Although the spearmint plant bears a resemblance to the peppermint plant, there is no difficulty in separating the two on the basis of odor and appearance.

"**Thyme** is the dried leaves and flowering tops of *Thymus vulgaris* L. It contains not more than 14 per cent of total ash, nor more than 4 per cent of ash insoluble in hydrochloric acid." Thyme is indigenous to the region of the Mediterranean, but may be grown all over the temperate zone. Thymol ($C_{10}H_{13}OH$) is one of the principal constituents of the oil of thyme, which is the volatile oil obtained from thyme. Thyme is used to flavor foods.

"**Tarragon** is the dried leaves and flowering tops of *Artemisia dracunculis* L." This condiment is used especially in certain parts of Asia. Tarragon may be bought green or dried. The dried material may be canned. France produces distilled essential oil of tarragon. Tarragon is used chiefly in "tarragon vinegar" and in flavoring soups.

Wintergreen.—The leaves of the wintergreen plant, *Gaultheria procumbens* L., are distilled to obtain wintergreen oil, a volatile oil. Methylsalicylate, and sweet birch oil (an oil resembling wintergreen oil in many respects) are often used in place of oil of wintergreen. The wintergreen plant—known in some places as the checkerberry, tea berry, or partridge-berry plant—grows wild in the Northern part of the United States. Oil of wintergreen is used principally as a flavoring for confectionery and beverages.

"**Bay leaves** are the dried leaves of *Laurus nobilis* L." This plant is cultivated in suitable localities in the temperate zone and is indigenous to the Mediterranean region. Bay leaf, or sweet bay as it is sometimes called, is used to flavor foods.

Sweet marjoram, a plant native to North America and grown as a garden herb in many regions, grows in the wild state in Portugal and Andalusia. It is used in medicinal preparations and as a food flavoring.

"**Cinnamon** is the dried bark of cultivated varieties of *Cinnamomum zeylanicum* Nees or of *C. cassia* (L.) Blume, from which the outer layers may or may not have been removed.

"*Ceylon cinnamon* is the dried inner bark of cultivated varieties of *Cinnamomum zeylanicum* Nees.

"*Ground cinnamon*, ground cassia, is the powder made from cinnamon. It contains not more than 5 per cent of total ash, nor more than 2 per cent of ash insoluble in hydrochloric acid."

Cinnamon and cassia are terms which are used interchangeably, yet they are representative of two separate species of the genus Cinnamomum.

Some cinnamon (*C. zeylanicum*) is grown in Ceylon, in Sumatra, in Java, and in tropical parts of Asia. Longitudinal strips of the very thin inner bark are removed from the trees (which range from 20 to 30 ft. in height), cured, and then dried. The oil found in cinnamon bark is very sweet and contains cinnamic aldehyde ($C_6H_5CH{:}CH.CHO$). Cin-

namon oil constitutes usually 1 to 2 per cent of the bark and accounts for the pungent odor emitted from the bark.

Cassia is lower priced than cinnamon, for which it has been substituted as an adulterant. Cassia oil bears a strong resemblance to cinnamon oil in both flavor and composition, as cinnamic aldehyde is likewise an important constituent of cassia. Cassia is cultivated in India, Indo-China, and China. Saigon produces the best grades of cassia, while the poorest comes from China. "Cassia buds," also used for flavoring, "are the dried flower buds of China cassia."[1]

"**Cloves** are the dried flower buds of *Caryophyllus aromaticus* L. They contain not more than 5 per cent of clove stems, not less than 15 per cent of volatile ether extract, not less than 12 per cent of quercitannic acid (calculated from the total oxygen absorbed by the aqueous extract), not more than 10 per cent of crude fiber, not more than 7 per cent of total ash, nor more than 0.5 per cent of ash insoluble in hydrochloric acid."

The clove tree is an evergreen, which frequently attains a height of 40 ft. When the tree is around 7 years old it bears mature cloves. After this the tree increases in productivity and may bear cloves for nearly 100 years.

Cloves were first secured in quantity from the Molucca Islands. The principal sources of cloves at present are the East Indies, the West Indies, British East Africa, Brazil, and India.

The volatile oil of cloves, which constitutes in some cases about 19 per cent of the cloves, is 70 to 85 per cent eugenol ($C_{10}H_{12}O_2$). Caryophyllin is also an important constituent of the oil. Resin, fixed oil, and quercitannic acid are present in cloves in varying quantities.

"**Saffron** is the dried stigma of *Crocus sativus* L. It contains not more than 10 per cent of yellow styles and other foreign matter, not more than 14 per cent of volatile matter when dried at 100°C., not more than 7.5 per cent of total ash, nor more than 1 per cent of ash insoluble in hydrochloric acid." Saffron is grown in Asia and Southern Europe. Besides its use in medicine, it is used as a flavor and also as a coloring matter for food. A red color is produced by carthanic acid, a constituent of saffron.

"**Red pepper** is the red, dried, ripe fruit of any species of Capsicum. It contains not more than 8 per cent of total ash, nor more than 1 per cent of ash insoluble in hydrochloric acid."

"**Capers** are the flower buds of *Capparis spinosa* L." The caper bush grows in Southern Europe in both the wild and cultivated states. The fresh capers are pickled in vinegar. The characteristic flavor of capers is imparted by capric acid, $CH_3(CH_2)_8COOH$. Nasturtium seeds

[1] LEACH, A. E., Food Inspection and Analysis.

and flower buds from other sources have been used as adulterants. The principal use of capers is for flavoring meats and pickles.

"**Allspice, pimento,** is the dried, nearly ripe fruit of *Pimenta officinalis* Lindl. It contains not less than 8 per cent of quercitannic acid (calculated from the total oxygen absorbed by the aqueous extract), not more than 25 per cent of crude fiber, not more than 6 per cent of total ash, nor more than 0.4 per cent of ash insoluble in hydrochloric acid."

Allspice is grown in the West Indies, Mexico and in the Northern part of South America.

The aroma of allspice resembles cloves and cassia. Like cloves, it possesses volatile oil and tannin, but also much starch. The oil which amounts to 3 to 4.5 per cent of allspice contains eugenol and a sesquiterpene, as does clove oil.

"**Paprika** is the dried, ripe fruit of *Capsicum annuum* L. It contains not more than 8.5 per cent of total ash, nor more than 1 per cent of ash insoluble in hydrochloric acid. The iodine number of its extracted oil is not less than 125, nor more than 136.

"*Hungarian paprika* is paprika having the pungency and flavor characteristic of that grown in Hungary.

"*a. Rosenpaprika,* rosapaprika, rose paprika, is Hungarian paprika prepared by grinding specially selected pods of paprika, from which the placentae, stalks, and stems have been removed. It contains no more seeds than the normal pods, not more than 18 per cent of nonvolatile ether extract, not more than 23 per cent of crude fiber, not more than 6 per cent of total ash, nor more than 0.4 per cent of ash insoluble in hydrochloric acid.

"*b. Koenigspaprika,* king's paprika, is Hungarian paprika prepared by grinding whole pods of paprika without selection, and includes the seeds and stems naturally occurring with the pods. It contains not more than 18 per cent of nonvolatile ether extract, not more than 23 per cent of crude fiber, not more than 6.5 per cent of total ash, nor more than 0.5 per cent of ash insoluble in hydrochloric acid.

"*Pimenton,* pimiento, Spanish paprika, is paprika having the characteristics of that grown in Spain. It contains not more than 18 per cent of nonvolatile ether extract, not more than 21 per cent of crude fiber, not more than 8.5 per cent of total ash, nor more than 1 per cent of ash insoluble in hydrochloric acid."

Paprika powder is deep red in color and is sweet and pungent. Paprika is one of the two principal kinds of red pepper, the other being cayenne pepper or cayenne.

Paprika, though grown in large quantities in Hungary, may be cultivated in any warm temperate climates. It is native to the American tropics.

"**Cayenne pepper,** Cayenne, is the dried, ripe fruit of *Capsicum frutescens* L., *C. baccatum* L., or some other small-fruited species of Capsicum. It contains not less than 15 per cent of nonvolatile ether extract, not more than 1.5 per cent of starch, not more than 28 per cent of crude fiber, not more than 8 per cent of total ash, nor more than 1.25 per cent of ash insoluble in hydrochloric acid."

Cayenne is cultivated in the same localities as paprika. It is known as "hot" pepper and is pungent.

At least part of the pungency found in paprika and cayenne is due to capsaicin, an alkaloid occurring in the seeds and particularly the pods. Resinous, mucilaginous, and red coloring matters, as well as an oil are characteristic of peppers.

The center of world pepper production is in the East Indies or Netherlands India, but vines are also grown commercially in British India, British Malaya, China, and the Philippines. Both white and black pepper come from the same plant, but the black pepper is the result of picking the berry when it is green or immature and drying it so that it shrivels up into a dark globule. If the same berries are allowed to ripen on the vine they eventually turn to a red color, which may be peeled to furnish the white pepper which is more esteemed in Europe. The latter type of pepper is more delicate in flavor and less pungent than the black pepper widely used in America.

The annual world production of pepper is approximately 75,000 long tons, of which about two-thirds is black pepper. In 1934 the United States imported about 35 million pounds of pepper, of which only a little over 10 per cent was white pepper.

"**Black pepper** is the dried immature berry of *Piper nigrum* L. It contains not less than 6.75 per cent of nonvolatile ether extract, not less than 30 per cent of starch, not more than 7 per cent of total ash, nor more than 1.5 per cent of ash insoluble in hydrochloric acid.

"*Ground black pepper* is the product made by grinding the entire berry of *Piper nigrum* L. It contains the several parts of the berry in their normal proportions.

"*Long pepper* is the dried fruit of *Piper longum* L."

"*White pepper* is the dried mature berry of *Piper nigrum* L. from which the outer coating or the outer and inner coatings have been removed. It contains not less than 7 per cent of nonvolatile ether extract, not less than 52 per cent of starch, not more than 5 per cent of crude fiber, not more than 3.5 per cent of total ash, nor more than 0.3 per cent of ash insoluble in hydrochloric acid."

The pepper plant is a shrub which attains a height up to 20 ft. Pepper is grown principally in the East Indies, but may be cultivated in the tropics quite generally.

The fruit is gathered as it begins to turn red. In the process of drying, it turns black. This is the black pepper of the market. It is customary to name varieties of black pepper according to the localities where grown or shipped.

White pepper is prepared from mature fruit. The outer, or outer and inner, coatings are removed by mechanical means or by permitting a slight fermentation followed by a rubbing between the hands. Drying follows.

Pepper contains an essential oil—$C_{10}H_{16}$—which imparts much of the pungent flavor; piperin ($C_{17}H_{19}NO_3$); piperidine; resin; and starch are important component parts.

Ground olive stones, pepper shells, buckwheat products and other materials have been used to adulterate pepper.

Juniper is the aromatic, dark blue fruit of *Juniperus communis*, an evergreen tree widely distributed in the Northern Hemisphere. Juniper is used to flavor corned beef and gin. It has medicinal uses, *e.g.*, juniper oil is a strong diuretic.

The vanilla bean is "the fruit of the plant of the *Vanilla planifolia*," a climbing vine belonging to the orchid family. The vanilla bean is cultivated in Mexico, Central and South America, the West and the East Indies, principally. The best products come from southern Mexico.

The vanilla bean is gathered when it has become a yellowish green. At this time, odor and characteristic color are lacking but are developed in the process of fermentation or sweating which follows. The older process, and one still used, consisted in placing the beans between blankets exposed to the sun and alternately pressing them lightly within the folds of the blanket and then permitting them access to the open air. Artificial heat in ovens has replaced this process to some degree. The beans are browned in the sun and the odor develops. Following the "sweating" process the beans are dried under cover.

The best cured beans are 8 to 10 in. long,[1] with drawn out ends and curved bases. They are soapy or waxy to the touch, dark brown in color, and coated with fine crystals of vanillin.

Vanillin ($C_8H_8O_3$) constitutes 1.2 to 3.5 per cent of the bean, and contributes largely to the flavor. The flavor and odor of the bean are not due to the vanillin concentration alone, however, for many beans less highly esteemed than the prized Mexican varieties contain a larger quantity of vanillin. It is the combination of vanillin with the other flavors and odors which imparts the high quality to the bean. In addition to the flavoring materials the vanilla bean contains fat, wax, sugar, gum, resin, and tannin. Vanilla extract is obtained by extracting vanilla

[1] LEACH, A. E., Food Analysis.

beans with dilute alcohol and adding cane sugar. Sometimes the extract may contain glycerin in addition. Imitation vanillas of low grade have been prepared from vanillin, coumarin, and Tahiti beans.

Synthetic vanillin is prepared by oxidizing the eugenol derived from the oil of cloves with alkaline potassium permanganate.

"**Mace** is the dried arillus of *Myristica fragrans* Houtt. It contains not less than 20 per cent nor more than 30 per cent of nonvolatile ether extract, not more than 10 per cent of crude fiber, not more than 3 per cent of total ash, nor more than 0.5 per cent of ash insoluble in hydrochloric acid. Macassar mace, Papua mace, is the dried arillus of *Myristica argentea* Warb.

"**Nutmeg** is the dried seed of *Myristica fragrans* Houtt, deprived of its testa, with or without a thin coating of lime (CaO). It contains not less than 25 per cent of nonvolatile ether extract, not more than 10 per cent of crude fiber, not more than 5 per cent of total ash, nor more than 0.5 per cent of ash insoluble in hydrochloric acid.

"*Macassar nutmeg*, Papua nutmeg, male nutmeg, long nutmeg, is the dried seed of *Myristica argentea* Warb, deprived of its testa."

Mace and *nutmeg* come from the same fruit of a tree grown in both the East and West Indies. The tree is similar in many respects to an orange tree and attains a height of 20 to 30 ft. The fruit is a drupe, about 5 cm. in diameter, and the crimson inner part of the fleshy portion covering the seed, when dried, constitutes mace. The seed of the fruit furnishes the kernels or nutmeg. Kernels may be lime-treated to prevent sprouting and insect depredations.

Nutmeg is made up of 25 to 35 per cent of fixed oil, 2.5 to 5 per cent of volatile oil, starch and albuminous material. Mace is similar in composition.

Mace (or nutmeg) is cultivated principally in the Molucca Islands in the East Indies and has also been introduced into the West Indies.

Mustard.—"*Ground mustard seed*, mustard meal, is the unbolted ground mustard seed and conforms to the standards for mustard seed.

"*Mustard cake* is ground mustard seed, mustard meal, from which a portion of fixed oil has been removed.

"*Mustard flour*, ground mustard, mustard, is the powder made from mustard seed with the hulls largely removed and with or without the removal of a portion of the fixed oil. It contains not more than 1.5 per cent of starch, nor more than 6 per cent of total ash.

"*Prepared mustard* is a paste composed of a mixture of ground mustard seed and/or mustard flour and/or mustard cake, with salt, a vinegar, and with or without sugar and/or dextrose, spices, or other condiments. In the fat-, salt-, and sugar-free solids it contains not more than 24 per cent of carbohydrates, not more than 12 per cent of crude fiber, nor less

than 5.6 per cent of nitrogen, the carbohydrates being calculated as starch."

The more common varieties of mustard are the black, brown (or Serepta), white (or yellow), and Indian. The plant of the black mustard (*Sinopis nigra*) produces the smallest seeds. They contain an enzyme, myrosin, the glucoside sinigrin, and 27 to 38 per cent of fixed oil. Sinigrin ($KC_{10}H_{18}NS_2O_{10}$, potassium myronate) is hydrolyzed in the presence of water by means of enzyme myrosin to glucose, potassium bisulphate, and mustard oil, a volatile oil.

Brown mustard comes from the small seeded *Sinapis juncea*. Brown and black mustards possess the most aroma, and are in general much alike.

White mustard comes from the largest seeds of *Sinapis alba*. Like black mustard these contain 27 to 38 per cent of fixed oil. Sinalbin, ($C_{30}H_{42}N_2S_2O_{15}$), a glucoside which forms a white nonvolatile mustard "oil" upon hydrolysis, replaces the sinigrin.

There is no starch present in mustard, hence it is a simple matter to detect the presence of such common adulterants as corn, rice, or wheat flour in ground mustard or mustard "flour."

Mustards are grown in gardens and frequently are seen growing wild. Charlock, a wild mustard, occurs commonly in America. Its seeds are sometimes used as an adulterant or diluent of cultivated mustard.

"**Dill seed** is the dried fruit of *Anethum graveolens* L. It contains not more than 10 per cent of total ash, nor more than 3 per cent of ash insoluble in hydrochloric acid."

The "dill pickle" is flavored with dill seeds. It is also used to flavor sauces and as a general condiment.

Dill is grown in Europe, especially in France, Spain, and Portugal and to some extent in this country.

"**Fennel seed** is the dried fruit of cultivated varieties of *Foeniculum vulgare* Hill. It contains not more than 9 per cent of total ash, nor more than 2 per cent of ash insoluble in hydrochloric acid."

The seed is sweet and aromatic, owing to a volatile oil. Seeds are used for oil production in some localities. Fennel is grown in the temperate zone.

"**Caraway,** caraway seeds, is the dried fruit of *Carum carvi* L. It contains not more than 8 per cent of total ash, nor more than 1.5 per cent of ash insoluble in hydrochloric acid."

Caraway seeds contain carvol ($C_{10}H_{14}O_6$), an essential oil.

Caraway is indigenous to Europe and may be grown in many regions.

"**Paradise seed,** grains of paradise, Guinea grains, malegueta pepper, is the seed of *Amomum melegueta* Roscoe." Paradise seeds are very pungent and are used to flavor certain liquors. Africa and the West Indies furnish much of the seeds.

"**Cardamom** is the dried, nearly ripe fruit of *Elettaria cardamomum* Maton. Cardamom seed is the dried seed of cardamom. It contains not more than 8 per cent of total ash, nor more than 3 per cent of ash insoluble in hydrochloric acid."

Cardamom seeds come from a small tree. The seeds are washed repeatedly in soap solutions before being dried.

Cardamom is grown chiefly in India. It is used as a flavoring in confectionery, drinks, and foods.

Bitter almond is a flavor derived from the oil of bitter almonds, which is extracted from the seeds of bitter almonds, peaches, or apricots. The seeds yield poisonous hydrocyanic acid (HCN) which must be separated out chemically.

"**Anise,** aniseed, is the dried fruit of *Pimpinella anisum* L. It contains not more than 9 per cent of total ash, nor more than 1.5 per cent of ash insoluble in hydrochloric acid." Aniseed is grown principally in Spain, Egypt, countries about the Mediterranean, India, and South America. Aniseed yields an oil with a sweet aromatic flavor. Aniseed is used to flavor confectionery, pastry, and drinks.

Tonka beans are the seeds of a tall tree, *Coumarouna odorata* Aublet, which grows in the South American tropics. The seeds yield coumarin ($C_9H_6O_2$), a material used in place of vanilla beans in the preparation of vanilla extract.

"**Cumin seed** is the dried fruit of *Cuminum cyminum* L. It contains not more than 9.5 per cent of total ash, not more than 1.5 per cent of ash insoluble in hydrochloric acid, nor more than 5 per cent of harmless foreign matter."

Cumin seed is grown in Europe and Asia. In Holland it is sometimes used to flavor cheese, in Germany as an additive for some kinds of bread, and in Norway in the preparation of anchovies. It is also used for soups, pickles, and foods in general.

"**Coriander seed** is the dried fruit of *Coriandrum sativum* L. It contains not more than 7 per cent of total ash, nor more than 1.5 per cent of ash insoluble in hydrochloric acid."

Coriander seed is indigenous to Southern Europe and Asia Minor. Flavor is due in large part to the volatile oil. It is used in confectionery, soups, pastries, and other foods.

"**Celery seed** is the dried fruit of *Celeri graveolens* L. Britton (*Apium graveolens* L.). It contains not more than 10 per cent of total ash, nor more than 2 per cent of ash insoluble in hydrochloric acid."

Celery is produced in large quantities in this country and Europe. Florida, California, New York, and Michigan are leading producers in the United States. The seeds from the celery plant are used to flavor pickles and other foods.

GINGER

Dried ginger is produced largely in West Indies, India, and Africa, Southeast Asia, and the Malay Archipelago, but the Jamaican product is usually considered the best. It is prepared from the underground stem or rhizome of an herbaceous perennial, *Zingiber officinale,* belonging to the natural order Zingiberaceae, a section of the Scitamineae. It has branching rhizomes which bear upright leafy shoots approximately 2 ft. in height and also a flowering shoot distinct from the others. The plant is cultivated by planting sections of the rhizome in a manner similar to that used in banana culture. It is believed that differences in ginger from various regions are dependent to a greater extent on the cultivation employed than on the variety.

Heavy rainfall and high temperatures are essential for ginger cultivation. Tropical climates are therefore especially favorable, although low temperatures in winter do no harm as the crop is out of the ground before the cooler season. Rich soils are necessary, but good drainage is essential to prevent rotting of the rhizomes. Fertilizers are necessary if the same plots are used year after year, particularly materials rich in lime and phosphates.

The best ginger is that obtained by yearly planting, in which case a section of the rhizome containing an "eye" or embryo stem is planted a few inches below the surface. When portions of the rhizome are left in the ground from year to year, the product is called rhizome ginger, which is considered of inferior quality as it is smaller and more fibrous.

When the leafy stalks become dry, shortly after flowering, the harvest starts. The rhizomes are pulled and lifted out of the ground, the dirt and rootlets removed, and the outer skin scraped off. Care is necessary in this operation as the oil cells lie immediately beneath the skin and contain the oil which gives the aroma of fine ginger. After peeling, the rhizomes are washed in water, sometimes soaked overnight, and then dried in the sun. Several days are required for complete drying. Unless the preparation is carefully conducted, the rhizomes may be injured by fungous growth.

In some countries the rhizomes are bleached by the use of limewater or by sulphur dioxide.

The preserved ginger of China is frequently made from young rhizomes grown only three months and not fully mature in order to have a less pungent flavor in the final product. After scraping such roots, they are punctured with holes, washed in rice water which is said to produce a better color, then boiled in several changes of sugar sirups, and finally treated with sugar.

Ginger is widely used as a spice in cooking, confections, pickled foods, in the manufacture of ginger ale and ginger beer, and also has some use in pharmaceutical preparations and as a volatile oil in perfume making.

FLAVORING EXTRACTS

A flavoring extract is a solution in ethyl alcohol of proper strength of the sapid and odorous principles derived from an aromatic plant, or parts of the plant, with or without its coloring matter, and conforms in name to the plant used in its preparation.

Vanilla extract is the flavoring extract prepared from vanilla bean, with or without sugar, dextrose, or glycerine, and contains in 100 cc. the soluble matters from not less than 10 grams of the vanilla bean.

Lemon extract is the flavoring extract prepared from oil of lemon or from lemon peel, or both, and contains not less than 5 per cent by volume of oil of lemon.

Ginger extract is the flavoring extract prepared from ginger and contains in each 100 cc. the alcohol-soluble matters from not less than 20 grams of ginger.

Peppermint extract is the flavoring extract prepared from oil of peppermint, or from peppermint, or both, and contains not less than 3 per cent by volume of oil of peppermint.

Wintergreen extract is the flavoring extract prepared from oil of wintergreen, and contains not less than 3 per cent by volume of oil of wintergreen.

The following are illustrations of synthetic or compounded flavors for clear beverages:

	Per Cent
Banana	
Benzyl acetate	10
Benzyl propionate	10
Ethyl butyrate	5
Amyl butyrate	10
Amyl acetate	5
Sweet orange oil	3
Lemon oil	4
Strawberry	
Benzyl acetate	10
Amyl acetate	20
Amyl butyrate	10
Ethyl butyrate	20
Ethyl acetate	5
Methyl salicylate	1
Ethyl cinnamate	1

Simple spice extracts are made up of solutions of volatile oils in dilute alcohol. Some of the more common spice extracts are allspice, anise, bitter almond, calamus, cardamom, cinnamon, cloves, coriander, fennel, ginger, mace, nutmeg, orange flower, and rose.

Flavoring extracts are prepared commonly in one of two ways: by maceration of the product in alcohol, or by solution in alcohol of the oil

which has been secured by pressure or distillation. Vanilla extract is prepared by finely grinding the bean and extracting it with ethyl alcohol, an example of the first method of preparing extracts. The method most frequently used is to dissolve the oil in alcohol. The following is a recipe for the manufacture of lemon flavoring extract:

Oil of lemon	50 cc.
Lemon peel, outer layer only	50 gm.
Alcohol, a sufficient quantity to make	1,000 cc.

Dissolve the oil in 900 cc. of alcohol, add the lemon peel, macerate for 48 hours, filter, and pass enough alcohol through the filter to make 1,000 cc.

Fruit flavors and extracts originally were obtained from vegetable sources. At present many flavors are synthetically prepared. Flavor in fruits is due to aldehydes, esters, and organic salts. Artificial flavors often contain impurities on account of their methods of manufacture.

Ethyl butyrate imparts the flavor of pineapple. This may be prepared from old butter and ethyl alcohol.

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